March 9, 1999

Mr. Vernon Persson, Chief
Division of Safety of Dams
Department of Water Resources
P.O. Box 942836
Sacramento, CA 94236-0001

Dear Mr. Persson:

Subject: Leroy Anderson Dam, No. 72-9, Santa Clara County
1998 Annual Summary Report and Analysis of Surveillance Data

Enclosed with this letter are two copies of our 1998 annual summary report for Leroy Anderson Dam.

This report includes a limited analysis of data from piezometers, crest and spillway training wall monuments, and visual reconnaissance. We also include information from the response of accelerometers owned by the United States Geological Survey.

The trends of the 1998 data are consistent with those previously observed and reported to DSOD. These trends indicate that the vertical and lateral movements of survey monuments, piezometric levels, and spillway underdrain flow rates are acceptable. There are no adverse or unexpected trends in the instrumental surveillance data. Visual observations of the dam and appurtenant structures indicate generally satisfactory conditions. Maintenance activities are summarized in the report.

If you have any questions or comments, please contact Mr. James L. Nelson (408) 265-2607, extension 2667, or Mr. Mohammad Khan at extension 2734.

Sincerely,

Original Signed By

James C. Wang, Ph.D., P.E.
Hydrology and Geology Services
Engineering Unit Manager

Enclosures

Cc: w/encl: R. Tepel, J. Sutcliffe, R. Fields, G. Faler, J. Wang, J. Aguilera, M. Khan, J. Nelson, File.

SANTA CLARA VALLEY WATER DISTRICT

DAM SURVEILLANCE EVALUATION REPORT

LEROY ANDERSON DAM

1998 ANNUAL REPORT

PREPARED FOR THE DIVISION OF SAFETY OF DAMS

SUBMITTED BY

SANTA CLARA VALLEY WATER DISTRICT

Stanley M. Williams
General Manager

James C. Wang
Hydrology and Geology Services
Engineering Unit Manager

MARCH 1999

March 9, 1999

Santa Clara Valley Water District

Mr. Vernon Persson, Chief
Division of Safety of Dams
Department of Water Resources
P.O. Box 942836
Sacramento CA 94236-0001

Subject: Leroy Anderson Dam, No. 72-9 - Santa Clara County

ANNUAL SUMMARY REPORT AND ANALYSIS OF SURVEILLANCE DATA

- Piezometer and Monthly Rainfall Data from January 1993 through December 1998
- Monument Data from January 1993 through December 1998
- Spillway Underdrain Flow Data from May 1993 through December 1998

INTRODUCTION

This annual summary report provides an analysis of January 1998 through December 1998 surveillance data from Leroy Anderson Dam, No. 72-9 and updates our last report titled "Annual Summary Report and Analysis of Surveillance Data," dated December 31, 1997.

Beginning with this report all pertinent surveillance data are presented using new vertical datum. The old datum used in our previous reports was based on National Geodetic Vertical Datum (NGVD) 1929. The new datum used in this and subsequent reports are based on North American Vertical Datum (NAVD) 1988. The new vertical datum is about 2.8 feet higher than the old datum.

Figure 1 shows the location of the surveillance points discussed below. Figure 2 shows both piezometers in cross section. Table 1 summarizes pertinent dam statistics. Table 2 summarizes 1993 to December 1998 piezometer and monthly rainfall data, Table 3 summarizes 1993 to December 1998 spillway underdrain flow data, and Table 4 summarizes 1993 to December 1998 dam crest monument survey data.

Piezometers are read monthly and the crest monuments are surveyed annually. Seepage at the spillway underdrain discharge point is measured seasonally as it occurs. Reported rainfall is measured at District Rain Gauge No. 41-2073, located a few hundred feet southeast of the left abutment of Leroy Anderson Dam.

SUMMARY OF FOUNDATION AND EMBANKMENT CONDITIONS

Information in this section is based on Wahler Associates' 1986 Inspection and Safety Review report of Leroy Anderson Dam, prepared in accordance with requirements of the Federal Energy

Regulatory Commission.

Foundation earth materials beneath the dam are rocks of the Jurassic-Cretaceous Franciscan Complex. Specifically, the lower right abutment is underlain by dense sandstone and shale, while the upper right abutment and upstream right abutment are underlain by soft, sheared serpentine. The serpentine extends from the upstream toe in the channel and cuts diagonally downstream across the right abutment. The serpentine/sandstone contact is characterized by a zone of crushed and faulted serpentine. Numerous faults mapped within the serpentine appear to be traces of the Coyote Creek fault system.

The dam embankment consists of a wide, central impervious core designated as Zones 2 and 3, flanked by upstream and downstream rockfill shells designated as Zones 1 and 4. Seepage control through the dam is provided by the downstream rockfill. A 20 to 30-foot-wide strip drain was constructed on the foundation beneath Zone 3 on the left side of the channel section. It appears this drain may have been constructed to control seepage from several springs that were apparently encountered during construction.

PIEZOMETER DATA

Figure 3 is a plot of reservoir water levels versus piezometric surface data, and monthly rainfall data, from January 1993 through December 1998. This surveillance period represents roughly six rainy seasons with generally normal to above normal rainfall. The beginning of 1993 rainy season marked the end of a relatively long drought that began in about 1987. The 1997-1998 rainy season was marked by an "El Niño" event, with most of the rainfall occurring from November through May. During this period, much of the San Francisco Bay Area received over 200 percent of normal rainfall. In particular, February 1997 was one of the wettest Februarys on record. Piezometric levels generally increased over this period, probably in response to generally greater storage over longer periods than in the past. There is some indication of a 5 to 6-month lag time between reservoir peaks and subsequent piezometric highs. The lag time between reservoir lows and the subsequent piezometric lows appear to be about 1 to 2 months.

Pneumatic piezometers PPA-1 and PPA-2 appear to have provided reliable data during the entire surveillance period.

A review of the piezometric data indicates that the embankment and its foundation are performing satisfactorily with respect to pore pressure.

SPILLWAY UNDERDRAIN FLOW DATA

Figure 4 is a plot of reservoir level versus spillway underdrain flow and monthly rainfall data from May 21, 1993 through December 16, 1998. Spillway underdrain flow has been measured when feasible by reading a water flowmeter installed on the central exit hole of the underdrain system. Readings are taken only when the reservoir is below the spillway weir elevation of

627.8 feet. In 1998, readings were taken from March 12 through December 16, 1998. The discharge hole is located about three feet below the lip of the spillway terminus. On July 8, 1998, the underdrain discharge was at an annual high of 166 gallons per minute (gpm). Since then, discharge has decreased, following the general downward trend of the reservoir level, to 63 gpm on December 16. It was noted that seepage rates had been higher in 1996 than in previous years. During the 1998 surveillance period, the maximum seepage rate was slightly higher than the maximum rate for 1996 (166 gpm versus 158 gpm). The measured flow is only a rough indication of total flow because other exit points also discharge water. Based on visual observation, it seems likely that the measured flow is between 1/3 and ½ of the total flow discharging from all underdrain exit points. It is not possible to observe underdrain discharges when the reservoir is spilling. Further studies are planned to evaluate the underdrain flows.

To protect the meter from damage, it is removed when the reservoir approaches spill. To prevent vandalism, the meter is removed when flows are low or cease during the summer months. This explains gaps in the data shown on Figure 4.

A brief report by Wahler Associates dated May 25, 1993, concluded that spillway underdrain flows were well within the range of past drain or weep hole flows into the original spillway, and no safety related concerns exist because the spillway slab is well-drained with substantial anchorage into the underlying bedrock.

MONUMENT DATA

Due to extensive dam crest modifications in 1987 and 1988, the original 15 crest monuments were destroyed and 16 new dam crest monuments (Monuments 16 through 31) were established. In addition, three new monuments (Monuments 13, 14, and 15) were established on the right and left spillway training walls (Figure 1).

In 1998, the monuments were surveyed on December 11 and 14. Figures 5, 6, and 7 are plots of monument survey data over the last 10 years in the Z (settlement), X, and Y directions, respectively. The July 20, 1988 date represents the first monument survey of the new monuments after the 1988 dam raising.

Beginning with this annual report, the District is providing plan view plots of resultant displacement vectors. Plan views of resultant vectors for total movement of downstream crest monuments, upstream crest monument, and spillway training wall monuments are shown in Figures 8, 10, and 12, respectively. The large arrows show total movement since 1988 and the small arrows show movement since the 1997 (last) survey. Figures 8, 10, and 12 can be used as overlays to Figures 9, 11, and 13, respectively, which are plan views of lateral monument displacement (Figure 1 shows locations of the X and Y axes).

Based on the 1998 survey data, the following are approximate maximum displacements experienced by the new crest monuments. Monuments 19 and 21 experienced a maximum

displacement of 0.27 foot in the negative X direction. Monuments 28, 29, and 30 experienced a maximum displacement of 0.08 foot in the negative Y direction (corresponding to resultant vector displacements of 0.10 foot and 0.11 foot). Monument 31 experienced a maximum displacement of 0.10 foot in the negative Y direction (corresponding to a resultant vector displacement of 0.12 foot). Monuments 21 and 24 experienced maximum displacements of 0.33 feet and 0.34 feet in the negative Z direction (settlement), respectively.

Based on the District's annual evaluation of crest monument survey data, we have identified what appears to be continuous downstream displacement of the dam crest monuments. In a letter dated April 2, 1997, DSOD requested that the District continue surveillance to monitor this trend with respect to safe operation of the dam. Based on the 1998 data, the observed downstream movement appears to have stabilized somewhat since the May 1996 survey. During the period from January 1997 to December 1998, most monuments along the crest of the dam have moved minor amounts (about 0.02 to 0.05 foot) either downstream or toward the left abutment, as shown by the small arrows on Figures 8 and 10. Since 1997, the spillway training wall monuments have moved 0.01 and 0.04 foot (Figure 12).

Displacements due to consolidation settlement have been within reasonable limits for the period of record presented here. Horizontal displacements of some crest monuments have approached about 0.3 foot in the downsteam direction. These movements have decreased in rate since 1996. We will continue to evaluate these movements.

INCLINOMETER DATA

An active landslide upstream of the left abutment is monitored by visual observation and by an inclinometer boring (SI-3). The inclinometer casing is only accessible when the reservoir water surface is below approximately elevation 576 feet (Figure 1).

Because the inclinometer boring has been submerged for the last several years the District has not been able to obtain inclinometer data from SI-3. Based on observations, it appears the landslide continues to move very slowly. When reservoir levels are low enough to gain access to the inclinometer boring, we will obtain inclinometer data. The data will be included in future reports.

VISUAL OBSERVATIONS

Dam and Appurtenant Structures

Visual observations are made by District employees during site visits for routine surveillance, operational, or other activities. For this report, District personnel performed visual inspections of Anderson Dam on December 27 and 29, 1998. No conditions were noted that warranted special attention during the period of January 1998 through December 1998.

Engineers from DSOD last performed a site visit at Leroy Anderson Dam on March 10, 1998. According to District employee Joe Aguilera, during their 1998 site visit, DSOD requested repair of erosional features described as "scalloped areas" on banks of the bedrock plunge pool area downstream of the spillway bucket. Erosional features were present on both banks about 50 feet downstream of the bucket. An erosional feature and associated "surface fissure" were present along the left bank along an approximate 50-foot-long section. These features were situated from bank crest to toe, about 180 to 230 feet downstream of the bucket. Other erosional features were present on both banks along an approximate 50-foot-long section, about 260 to 300 feet downstream of the bucket. The District plans to repair these features by adding rip rap and providing additional erosion protection of the plunge pool area by early 1999.

Visual observations are recorded to note the status of landslides in the immediate vicinity of the dam and appurtenant structures. A group of landslides occupy the area from the upstream left groin area to immediately east of the boat ramp. The sloping inlet structure is founded between two landslide areas. Based on observations it appears that the left abutment landslides remain dormant.

Small landslides are scattered along the northeasterly slope of the spillway discharge channel. Field observations and examination of aerial photographs confirm that these landslides do not significantly block the discharge channel at this time.

Reservoir Area

Reservoir area landslides are monitored by field inspections and by aerial photographic interpretation. While the landslides are numerous, and intermittently active, they are not a threat to the functionality or safety of the dam and appurtenant structures.

LOCAL SEISMICITY DURING JANUARY 1998 THROUGH DECEMBER 1998

A discussion of historic seismicity in the vicinity of Anderson Dam prior to 1998 is presented in our previous annual reports for the dam. Seismic information was obtained from the U.S. Geological Survey National Strong-Motion Program Internet site (U.S.G.S., 1998) and the Northern California Earthquake Data Center Internet site at Berkeley (Northern California Earthquake Data Center, 1998).

During the period January 1998 through December 1998, there was only one significant earthquake in the vicinity of Anderson Dam. Significant earthquakes are defined as those with local magnitudes (M_L) of about 5 or greater within about 50 miles of District Dams. On August 12, 1998, a magnitude 5.35 earthquake (M_L) occurred in the vicinity of San Juan Bautista, in San Benito County. The epicenter of this earthquake was located about 30 miles southeast of Anderson Dam, as shown on Figure 17. This earthquake has been informally named the "San Juan Bautista" earthquake by the U.S.G.S. A post-earthquake inspection of Anderson Dam by

District personnel on August 12, 1998 did not reveal any significant damage due to earthquake effects.

Noteworthy, but less significant earthquakes, with approximate magnitudes of 4.0 (M_L) occurred at five locations in the San Francisco Bay Area, during 1998 (Figure 17). On May 28, 1998, a magnitude 4.4 earthquake occurred near Hollister, California, about 25 miles south-southeast of the dam. On June 15, 1998, a magnitude 4.01 earthquake occurred about 12 miles southeast of the dam. On October 10, 1998, a magnitude 4.01 earthquake occurred about 14½ miles south-southeast of the dam. On December 4, 1998, a magnitude 4.12 earthquake occurred in the Berkeley area about 63 miles northwest of the dam. On December 29, 1998, a swarm of about 10 earthquakes of magnitude 1.1 to 4.0 occurred in the Ben Lomond area of Santa Cruz County, about 23 miles west of the dam. Four of these earthquakes in the swarm had magnitudes of 3.0, 3.5, 3.8, and 4.0. Because these noteworthy earthquakes were less than magnitude 5 (the approximate threshold for significant earthquakes as defined by the District), the District did not perform post-earthquake inspections or survey the monuments.

The United States Geological Survey operates an array of accelerometers at and near Anderson Dam. Locations of the accelerometers in the vicinity of the dam are shown in Figure 1. Information from the accelerometers was only available for the August 12, 1998, San Juan Bautista earthquake. Accelerations from the four earthquakes of approximate 4.0 magnitude were not significant enough to trigger the instruments. During the San Juan Bautista earthquake the instruments recorded a vertical acceleration of 0.01 g and horizontal accelerations of 0.03 g.

CHANGES IN SURVEILLANCE PROGRAM, DAM AND APPURTENANT STRUCTURES, AND OPERATIONS AND MAINTENANCE

Overall, for the period January 1998 through December 1998, no significant modifications of the dam or appurtenant structures occurred, and no operational changes were made that would impact dam performance.

We plan to add a set of crest monuments along the centerline of the dam crest. These monuments should give a better indication of the behavior of the core of the dam and provide additional data on long-term displacements of the crest of the dam. DSOD inspectors have requested that the spillway underdrain seepage from the central and left drain exits be captured and monitored on a full-time basis. Construction to direct the seepage to independent weirs is planned for summer, 1999.

CONCLUSIONS

Since 1988, cumulative maximum lateral displacement of the crest is about 0.27 foot downstream at Monuments 19 and 21. Monuments 28, 29, and 30 experienced a maximum

displacement of 0.08 foot in the negative Y direction (corresponding to resultant vector displacements of 0.10 foot and 0.11 foot). Monument 31 experienced a maximum displacement of 0.10 foot in the negative Y direction (corresponding to a resultant vector displacement of 0.12 foot). The downstream displacement of crest monuments appears to have stabilized since May 1996. Cumulative maximum settlement is 0.34 foot at Monument 24. During the period from January 1997 to December 1998, most monuments along the crest of the dam have moved minor amounts (about 0.02 to 0.05 foot) either downstream or toward the left abutment, as shown by the small arrows on Figures 8 and 10. Since 1997, the spillway training wall monuments have moved 0.01 and 0.04 foot (Figure 12). Leroy Anderson Dam has responded safely to one significant seismic event in the past year. Review of the surveillance data shows a normal response of the dam to its environment, aging process, and external events. The District will continue with the current monitoring program and will keep DSOD informed of any significant changes pertaining to the surveillance of Leroy Anderson Dam.

Piezometer data indicate that there has not been any significant increase in pore pressure in the dam core that would undermine the dam stability.

Report Prepared by:

James L. Nelson, C.E.G.
Assistant Engineering Geologist

Mohammad Khan , P.E
Associate Civil Engineer (Geotechnical)

Attachments:

1. Table 1 - Pertinent Dam Statistics (As-built modifications, 1988)
2. Table 2 - 1993 to November 1998 Piezometer and Monthly Rainfall Data
3. Table 3 - 1993 to 1998 Spillway Underdrain Flow Data
4. Table 4 - 1993 to 1998 Monument Survey Data
5. Figure 1 – Topographic Map
6. Figure 2 - Cross Section
7. Figure 3 - Reservoir Water Level, Piezometric Surfaces, and Monthly Rainfall, January 1993 through December 1998
8. Figure 4 - Reservoir Level, Spillway Underdrain Flow, and Monthly Rainfall, May 1993 through December 1998
9. Figure 5 – Ten Year Plot of Monument Z Direction (Vertical) Displacement Versus Time, July 1988 through December 1998
10. Figure 6 – Ten Year Plot of Monument X Direction Displacement Versus Time, July 1988 through December 1998
11. Figure 7 – Ten Year Plot of Monument Y Direction Displacement Versus Time, July

1988 through December 1998

12. Figure 8 – Relative Displacement Vectors of Downstream Crest Monument Lateral Location Surveys, July 1988 through December 1998
13. Figure 9 – Downstream Crest Monument Lateral Location Surveys in Plan View, June 1991 through December 1998
14. Figure 10 – Relative Displacement Vectors of Upstream Crest Monument Lateral Location Surveys, July 1988 through December 1998
15. Figure 11 - Upstream Crest Monument Lateral Location Surveys in Plan View, June 1991 through December 1998
16. Figure 12 – Relative Displacement Vectors of Spillway Training Wall Monument Lateral Location Surveys, July 1988 through December 1998
17. Figure 13 – Spillway Training Wall Monument Lateral Location Surveys in Plan View, June 1991 through December 1998
18. Figure 14 - Downstream Crest Monument Vertical Location Surveys in Section View, June 1991 through December 1998
19. Figure 15 - Upstream Crest Monument Vertical Location Surveys in Section View, June 1991 through December 1998
20. Figure 16 - Spillway Training Wall Monument Vertical Location Surveys in Section View, June 1991 through December 1998
21. Figure 17 - Regional Fault Map, Showing Significant and Noteworthy Earthquakes within 65 Miles of Leroy Anderson Dam, January 1997 through December 1998

bcc: R. Tepel, J. Sutcliffe, R. Fields, G. Faler, J. Wang, J. Aguilera, M. Khan, J. Nelson, File.

TABLE 1
Pertinent Dam Statistics (As-built modifications, 1988)
Leroy Anderson Dam

DSOD No.	Year Completed	Type	Dam Height ft	Dam Crest Length ft	Storage Capacity (acre-ft)	Dam Crest Elev. ft	Spillway Crest Elev. ft	Total Freeboard ft
72-9	1950	Rolled Earth & Rock Fill	240	1,385	89,073	6463	627.8	18.5

Note: basis of elevations is NAVD 1988 - values in this table are 2.8 feet higher than those in reports submitted prior to 1998

2.8

6467.3

TABLE 2
1993 to 1998 Piezometer and Monthly Rainfall Data
Leroy Anderson Dam

Date	Reservoir Level (ft)	PPA-1 Piezometric Surface Elevation (ft)	PPA-2 Piezometric Surface Elevation (ft)	Monthly* Rainfall (in)
01/20/93	549.32	552.27	473.61	9.48
02/17/93	592.28	552.96	474.07	6.59
03/17/93	619.85	553.43	477.53	2.36
04/20/93	626.38	553.89	AH	0.47
05/19/93	623.35	555.04	481.00	0.67
06/16/93	621.30	555.51	482.61	0.64
07/14/93	620.36	553.89	485.62	0.00
08/18/93	617.65	558.05	486.31	0.00
09/16/93	612.35	558.97	AH	0.00
10/28/93	606.05	564.05	491.16	0.43
11/18/93	605.82	562.67	AH	1.70
12/20/93	605.52	563.13	493.70	1.50
1/18/94	604.55	567.06	492.78	1.88
02/17/94	604.98	567.98	493.93	4.35
03/23/94	606.28	568.67	494.40	0.55
04/26/94	602.65	569.37	494.63	0.91
05/17/94	598.42	569.37	494.63	1.54
06/22/94	591.82	569.83	494.86	0.00
07/20/94	589.62	567.52	492.32	0.00
08/16/94	587.02	568.67	494.40	0.00
09/19/94	583.48	567.75	491.85	0.00
10/12/94	581.32	569.13	492.55	0.39
11/16/94	574.78	567.75	491.85	2.02
12/15/94	573.85	567.75	490.93	1.50
01/17/95	585.82	565.90	490.01	11.11
02/15/95	609.08	565.44	491.85	0.59
03/15/95	624.22	564.98	492.09	9.09
04/18/95	627.08	568.44	495.32	1.44
05/17/95	627.23	568.21	497.17	0.56
06/14/95	627.09	574.91	499.02	0.48
07/17/95	625.08	576.99	498.32	0.00
08/15/95	622.11	578.84	501.56	0.00
09/19/95	617.58	579.76	501.79	0.00
10/17/95	611.78	579.53	500.63	0.12
11/15/95	607.46	AH	499.02	0.00
12/18/95	607.48	577.68	499.94	6.34
01/19/96	606.01	573.99	498.78	3.34
02/16/96	618.44	574.91	498.09	7.57
03/18/96	627.44	575.37	500.17	2.44

TABLE 2
1993 to 1998 Piezometer and Monthly Rainfall Data
Leroy Anderson Dam

Date	Reservoir Level (ft)	PPA-1 Piezometric Surface Elevation (ft)	PPA-2 Piezometric Surface Elevation (ft)	Monthly* Rainfall (in)
04/15/96	627.11	578.14	500.40	0.94
05/20/96	625.93	579.30	501.09	1.69
06/17/96	621.17	578.37	501.56	0.00
07/15/96	616.35	580.45	502.94	0.00
8/19/96	610.63	582.76	502.71	0.00
9/12/96	608.02	579.76	502.25	0.00
10/17/96	602.22	578.61	502.48	1.46
11/19/96	602.06	576.53	500.40	2.39
12/6/96	600.57	576.30	499.02	7.28
1/16/97	626.16	576.53	501.09	11.11
2/18/97	626.68	577.22	502.94	0.08
3/17/97	621.46	578.14	503.64	0.16
4/14/97	621.24	579.99	503.17	0.00
5/15/97	620.00	579.53	501.33	0.16
6/24/97	617.31	576.76	503.87	0.04
7/15/97	614.36	582.76	503.87	0.00
8/18/97	607.17	581.38	503.40	0.08
9/23/97	602.22	579.76	503.64	0.00
10/14/97	599.59	578.37	499.71	0.40
11/19/97	595.15	577.22	500.17	4.22
12/15/97	591.22	575.83	497.63	2.32
1/21/98	596.09	574.91	495.55	6.42
2/17/98	629.14	576.53	500.40	12.05
3/16/98	626.06	577.03	502.02	2.44
4/16/98	627.10	578.84	502.71	1.50
5/18/98	627.00	580.22	501.33	2.36
6/22/98	627.33	582.35	504.91	0.00
7/14/98	625.10	584.38	505.25	0.00
8/17/98	619.80	584.15	505.48	0.00
9/15/98	614.60	583.69	505.48	0.16
10/14/98	611.30	583.23	499.71	0.51
11/17/98	609.80	581.61	504.10	2.73
12/14/98	605.89	580.92	502.02	0.79

Notes:

1) basis of elevations is NAVD 1988 - values in this table are 2.8 feet higher than those in reports submitted prior to 1998 .
2) * = total rainfall at end of indicated month in Date column
3) AH = anomalously high reading

TABLE 3
1993 to 1998 Spillway Underdrain Flow Data
Leroy Anderson Dam

Date	Reservoir Level (ft)	Underdrain Flow (gpm)	Date	Reservoir Level (ft)	Underdrain Flow (gpm)	Date	Reservoir Level (ft)	Underdrain Flow (gpm)
05/21/93	623.22	87	06/29/93	620.95	122	10/01/93	609.82	82
05/22/93	623.12	126	06/30/93	620.95	121	10/04/93	609.28	80
05/23/93	623.02	120	07/01/93	620.92	122	10/08/93	608.68	79
05/24/93	622.95	131	07/02/93	620.88	122	10/11/93	608.28	78
05/25/93	622.92	125	07/03/93	620.82	121	10/14/93	607.92	76
05/26/93	622.82	124	07/04/93	620.78	121	10/18/93	607.55	76
05/27/93	622.75	124	07/05/93	620.75	121	10/21/93	607.12	75
05/28/93	622.65	123	07/06/93	620.72	121	10/25/93	606.42	74
05/29/93	622.58	124	07/07/93	620.68	121	10/28/93	606.05	72
05/30/93	622.52	123	07/08/93	620.65	121	02/22/94	605.48	66
05/31/93	622.42	124	07/09/93	620.62	121	02/24/94	605.48	43
06/01/93	622.35	123	07/11/93	620.52	121	02/28/94	606.98	60
06/02/93	622.25	123	07/12/93	620.48	121	03/03/94	607.48	63
06/03/93	622.15	123	07/13/93	620.45	121	03/07/94	606.85	65
06/04/93	622.08	124	07/14/93	620.38	121	03/10/94	606.38	64
06/05/93	622.02	124	07/15/93	620.35	121	03/17/94	606.32	63
06/06/93	621.95	124	07/16/93	620.32	121	03/21/94	606.32	62
06/07/93	621.92	123	07/19/93	620.22	120	03/24/94	606.28	63
06/08/93	621.85	124	07/22/93	620.08	120	03/28/94	606.35	63
06/09/93	621.78	113	07/27/93	619.95	120	03/31/94	606.32	61
06/10/93	621.72	126	07/29/93	619.88	120	04/04/94	606.32	61
06/11/93	621.65	122	08/02/93	619.75	120	04/07/94	606.02	61
06/12/93	621.58	122	08/06/93	619.52	120	04/11/94	605.38	59
06/13/93	621.52	103	08/09/93	619.08	120	04/14/94	604.88	60
06/14/93	621.45	125	08/12/93	618.62	118	04/18/94	604.18	53
06/15/93	621.38	122	08/16/93	617.95	116	04/21/94	603.55	39
06/16/93	621.35	122	08/19/93	617.48	114	04/25/94	602.75	37
06/18/93	621.22	122	08/23/93	616.85	112	04/28/94	602.35	34
06/19/93	621.22	121	08/27/93	616.12	109	05/02/94	601.62	32
06/20/93	621.18	121	08/30/93	615.45	107	05/05/94	601.12	35
06/21/93	621.15	123	09/02/93	614.85	104	05/09/94	600.45	31
06/22/93	621.12	121	09/07/93	613.98	100	05/12/94	599.75	26
06/23/93	621.12	121	09/09/93	613.62	94	05/16/94	598.68	24
06/24/93	621.08	122	09/13/93	612.85	91	05/19/94	598.08	28
06/25/93	621.08	122	09/16/93	612.35	88	05/23/94	597.25	24
06/26/93	621.08	123	09/20/93	611.82	87	05/26/94	596.45	21
06/27/93	621.05	121	09/23/93	611.25	86	05/31/94	594.85	17
06/28/93	621.02	122	09/27/93	610.52	84	06/02/94	594.32	3

TABLE 3
1993 to 1998 Spillway Underdrain Flow Data
Leroy Anderson Dam

Date	Reservoir Level (ft)	Underdrain Flow (gpm)	Date	Reservoir Level (ft)	Underdrain Flow (gpm)	Date	Reservoir Level (ft)	Underdrain Flow (gpm)
06/06/94	593.82	2	09/05/95	619.58	116	06/17/96	621.17	143
06/09/94	593.45	0	09/07/95	619.42	116	06/20/96	620.70	142
06/16/94	592.58	0	09/18/95	617.75	114	06/25/96	619.86	139
06/23/94	591.72	0	09/25/95	616.52	104	06/27/96	619.54	137
03/02/95	609.22	37	09/28/95	616.08	102	07/01/96	618.88	121
03/06/95	609.28	38	10/02/95	615.58	101	07/11/96	617.08	110
03/09/95	609.35	39	10/12/95	613.03	95	07/15/96	616.35	125
03/11/95	615.58	52	10/16/95	612.00	87	07/19/96	615.67	121
05/11/95	626.82	109	10/19/95	611.42	85	07/22/96	615.09	121
05/15/95	627.02	114	10/26/95	610.09	81	07/25/96	614.47	119
05/18/95	627.18	115	10/30/95	609.34	78	07/29/96	613.67	116
05/22/95	627.32	117	11/02/95	608.84	75	08/01/96	613.01	113
05/25/95	627.38	119	11/09/95	607.53	72	08/05/96	612.58	110
05/30/95	627.52	121	11/13/95	607.47	67	08/12/96	611.52	106
06/05/95	627.32	123	11/16/95	607.46	66	08/16/96	611.00	101
06/08/95	627.18	127	11/20/95	607.22	65	08/19/96	610.63	98
06/12/95	626.95	127	11/27/95	607.15	64	08/22/96	610.29	96
06/15/95	627.05	129	12/07/95	609.10	64	08/26/96	609.86	94
06/19/95	626.75	130	12/11/95	607.04	64	08/29/96	609.56	90
06/26/95	626.45	130	12/18/95	607.48	71	09/05/96	608.81	88
06/29/95	626.25	131	12/21/95	606.65	67	09/12/96	608.02	83
07/03/95	626.02	104	12/26/95	605.95	65	09/16/96	607.56	79
07/06/95	625.82	85	12/28/95	605.96	55	09/30/96	606.26	73
07/10/95	625.52	128	01/04/96	606.06	61	10/03/96	605.76	69
07/13/95	625.32	128	01/08/96	605.97	59	10/07/96	604.63	66
07/17/95	625.08	128	01/11/96	605.95	58	10/10/96	603.87	61
07/20/95	624.88	128	01/18/96	605.97	59	10/17/96	602.22	56
07/24/95	624.55	128	01/25/96	606.42	61	10/22/96	601.22	49
07/27/95	624.38	128	02/05/96	614.52	72	10/24/96	601.30	46
07/31/95	624.08	128	05/13/96	626.62	157	10/28/96	601.55	46
08/03/95	623.82	127	5/16/96	626.39	158	11/01/96	601.81	48
08/07/95	623.25	126	5/21/96	625.86	158	11/07/96	602.10	45
08/10/95	622.82	125	5/23/96	625.63	155	11/14/96	602.29	46
08/14/95	622.28	124	5/28/96	624.94	155	11/18/96	602.16	48
08/17/95	621.85	122	06/04/96	623.16	151	11/25/96	601.65	48
08/24/95	620.95	121	06/06/96	622.73	146	12/05/96	600.64	43
08/28/95	620.42	119	06/10/96	622.14	146	12/09/96	600.50	41
08/31/95	620.08	119	06/13/96	621.70	145	12/12/96	601.29	46

TABLE 3
1993 to 1998 Spillway Underdrain Flow Data
Leroy Anderson Dam

Date	Reservoir Level (ft)	Underdrain Flow (gpm)	Date	Reservoir Level (ft)	Underdrain Flow (gpm)	Date	Reservoir Level (ft)	Underdrain Flow (gpm)
12/16/96	601.00	42	5/6/98	627.28	159			
12/19/96	600.77	40	5/13/98	627.12	161			
12/23/96	602.58	46	5/21/98	626.96	161			
12/30/96	603.23	48	5/28/98	627.29	161			
1/2/97	611.60	58	6/3/98	627.01	162			
6/11/97	618.32	133	6/10/98	626.96	160			
6/18/97	617.80	132	6/24/98	626.88	162			
6/26/97	617.13	130	7/8/98	625.85	166			
7/2/97	616.20	126	7/15/98	624.96	163			
7/9/97	615.25	122	7/29/98	623.35	156			
7/16/97	614.21	118	8/5/98	622.29	150			
8/6/97	610.07	107	8/12/98	620.90	145			
8/14/97	608.08	91	8/19/98	619.50	136			
8/20/97	606.77	81	8/26/98	618.20	131			
8/27/97	605.56	73	9/2/98	616.88	124			
9/3/97	604.31	64	9/10/98	615.43	117			
9/10/97	603.49	57	9/30/98	612.62	106			
9/17/97	603.02	53	10/7/98	611.93	99			
9/24/97	602.16	50	10/14/98	611.26	95			
10/1/97	601.59	41	10/22/98	610.52	91			
10/8/97	601.02	44	10/29/98	609.84	88			
10/15/97	599.41	40	11/5/98	610.12	84			
10/22/97	598.31	34	11/12/98	610.46	87			
10/29/97	598.37	29	11/18/98	609.62	84			
11/5/97	597.43	28	11/25/98	608.37	79			
11/13/97	596.09	25	12/4/98	607.27	75			
11/19/97	595.15	22	12/9/98	606.70	69			
12/4/97	592.56	14	12/16/98	605.81	63			
12/10/97	591.70	9						
12/17/97	590.96	1						
3/12/98	626.36	130						
3/18/98	625.86	133						
3/25/98	627.28	136						
4/1/98	627.23	144						
4/8/98	626.97	146						
4/15/98	627.09	149						
4/22/98	627.16	152						
4/29/98	627.42	155						

Note: 1) NR = Underdrain flow not recorded 2) gpm = gallons per minute
3) Basis of reservoir elevations is NAVD 1988 - values in this table are 2.8 feet higher than those in reports submitted prior to 1998

TABLE 4
1993 through 1998 Monument Survey Data
Leroy Anderson Dam

Date	Monument Z Direction (Vertical) Displacement (feet)																		
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1/27/93	0.01	-0.03	-0.03	-0.01	-0.09	-0.11	-0.27	-0.21	-0.32	-0.26	-0.23	-0.35	-0.18	-0.16	-0.09	-0.05	-0.04	-0.04	-0.06
1/11/94	-0.02	-0.01	-0.01	0.01	-0.08	-0.07	-0.24	-0.18	-0.29	-0.25	-0.22	-0.35	-0.20	-0.16	-0.11	-0.06	-0.04	-0.03	-0.05
12/05/94	NR	NR	NR	0.02	-0.06	-0.06	-0.23	-0.17	-0.29	-0.24	-0.18	-0.30	-0.14	-0.13	-0.06	-0.02	0.00	0.02	NR
1/4/96	NR	NR	NR	-0.05	-0.12	-0.11	-0.25	-0.18	-0.30	-0.25	-0.19	-0.31	-0.14	-0.13	-0.07	-0.04	-0.03	-0.02	-0.01
5/22/96*	NR	NR	NR	0.01	-0.06	-0.04	-0.20	-0.15	-0.27	-0.24	-0.18	-0.30	-0.13	-0.12	-0.05	-0.01	-0.01	0.01	-0.01
1/29/97	NR	-0.08	-0.03	0.02	-0.05	-0.06	-0.26	-0.19	-0.34	-0.30	-0.22	-0.37	-0.18	-0.17	-0.10	-0.08	-0.03	-0.01	-0.02
12/11/98	0.00	-0.02	-0.01	0.01	-0.08	-0.07	-0.25	-0.19	-0.33	-0.28	-0.22	-0.34	-0.17	-0.15	-0.08	-0.04	-0.02	0.00	-0.01
12/3/99	0	-.01	0	.01	-.07	-.07	-.25	-.19	-.32	-.28	-.21	-.35	-.17	-.14	-.08	-.03	-.01	.01	-.01

Date	Monument X Direction Displacement (feet)																		
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1/27/93	-0.10	-0.03	-0.03	-0.09	-0.12	-0.04	-0.12	-0.03	-0.09	-0.02	-0.07	-0.12	-0.01	-0.06	-0.02	-0.06	-0.05	-0.06	-0.06
1/11/94	-0.07	-0.06	-0.04	-0.09	-0.13	-0.07	-0.18	-0.09	-0.17	-0.08	-0.12	-0.17	-0.04	-0.09	-0.03	-0.06	-0.04	-0.06	-0.05
12/05/94	-0.05	-0.03	-0.03	-0.09	-0.13	-0.06	-0.17	-0.08	-0.16	-0.07	-0.12	-0.18	-0.04	-0.09	-0.03	-0.07	-0.05	-0.06	-0.06
1/4/96	-0.03	0.01	0.00	-0.09	-0.14	-0.09	-0.22	-0.13	-0.21	-0.12	-0.15	-0.23	-0.06	-0.12	-0.03	-0.08	-0.06	-0.08	-0.07
5/22/96*	NR	NR	NR	-0.10	-0.13	-0.10	-0.24	-0.15	-0.23	-0.12	-0.19	-0.25	-0.09	-0.15	-0.05	-0.10	-0.08	-0.09	-0.07
1/29/97	NR	-0.02	-0.03	-0.10	-0.15	-0.11	-0.24	-0.16	-0.25	-0.14	-0.20	-0.24	-0.09	-0.14	-0.05	-0.09	-0.07	-0.07	-0.08
12/11/98	-0.02	-0.03	-0.02	-0.09	-0.18	-0.17	-0.27	-0.19	-0.27	-0.15	-0.19	-0.23	-0.07	-0.11	-0.02	-0.08	-0.05	-0.08	-0.07

TABLE 4
1993 through 1998 Monument Survey Data
Leroy Anderson Dam

Date	Monument Y Direction Displacement (feet)																		
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1/27/93	-0.07	-0.07	-0.06	-0.06	-0.07	-0.10	-0.06	-0.10	-0.05	-0.05	-0.01	0.00	-0.02	-0.01	-0.03	-0.03	-0.05	-0.04	-0.06
1/11/94	-0.08	-0.05	-0.04	-0.06	-0.07	-0.10	-0.06	-0.09	-0.02	-0.04	0.00	0.01	0.01	-0.01	-0.01	-0.04	-0.03	-0.03	-0.05
12/05/94	-0.09	-0.07	-0.07	-0.06	-0.07	-0.10	-0.06	-0.10	-0.05	-0.06	0.00	0.01	-0.01	-0.01	-0.01	-0.04	-0.04	-0.04	-0.05
1/4/96	-0.07	-0.09	-0.04	-0.06	-0.08	-0.11	-0.06	-0.11	-0.04	-0.06	0.00	0.02	0.00	-0.01	-0.02	-0.04	-0.06	-0.05	-0.06
5/22/96*	NR	NR	NR	-0.05	-0.04	-0.06	-0.02	-0.05	0.01	-0.01	0.02	0.02	-0.01	-0.03	-0.04	-0.06	-0.06	-0.06	-0.07
1/29/97	NR	-0.05	-0.04	-0.04	-0.05	-0.07	-0.03	-0.06	0.00	-0.02	0.03	0.03	0.01	0.00	-0.02	-0.03	-0.03	-0.04	-0.05
12/11/98	-0.07	-0.05	-0.08	-0.06	-0.06	-0.07	-0.05	-0.06	-0.01	-0.03	-0.01	0.01	-0.03	-0.04	-0.06	-0.08	-0.08	-0.08	-0.10

Notes: 2/2/99 D

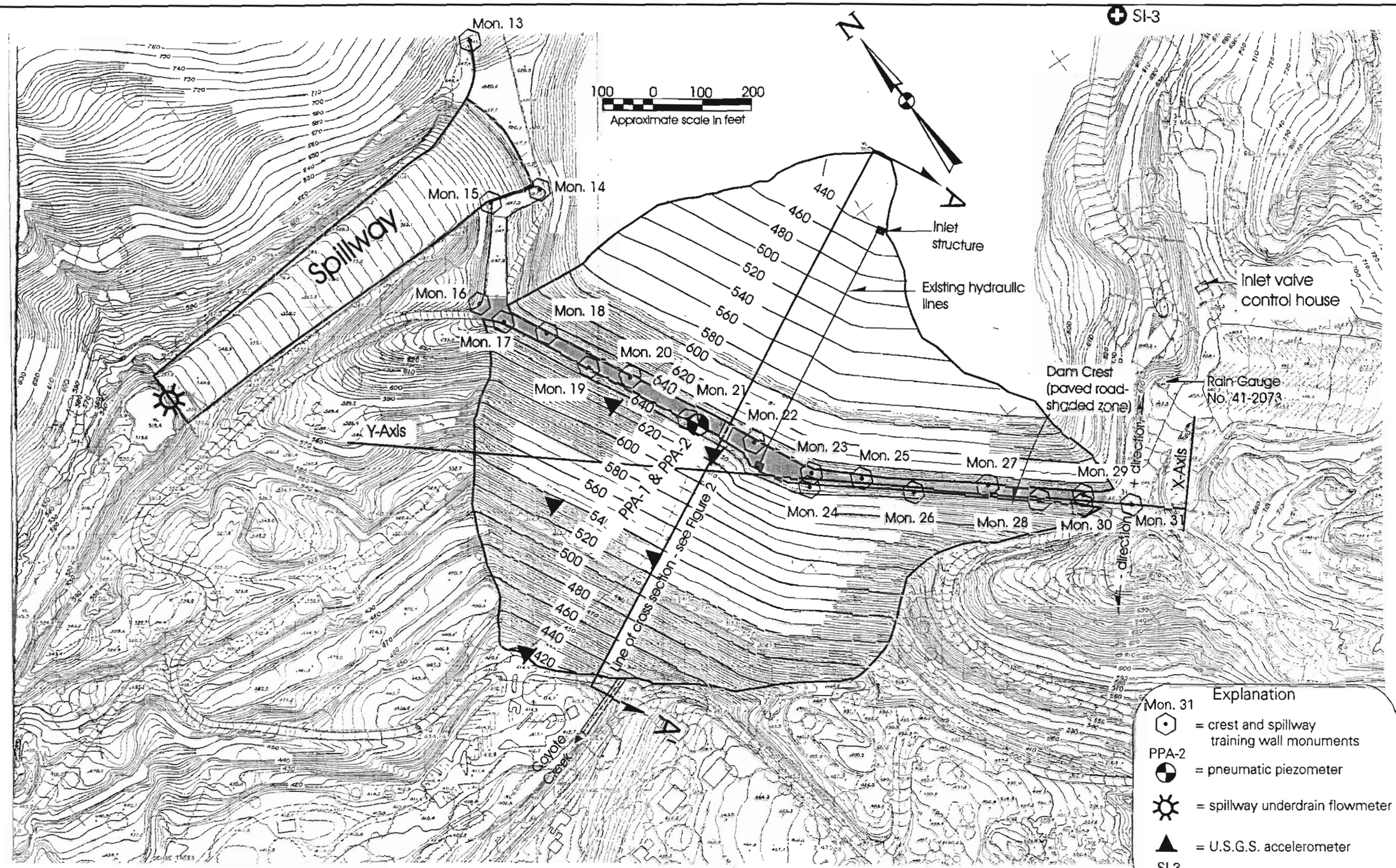
1) Negative vertical displacement signifies settlement
2) Positive vertical displacement signifies heave
3) Y direction displacement signifies longitudinal movement
4) Negative X direction displacement signifies downstream movement
5) Positive X direction displacement signifies upstream movement
6) NR = monument survey data not recorded
7) Displacement is net movement since 1988
8) * = special monument survey after May 21, 1996 earthquake

Resultant vectors based on X, Y, Z, data

	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1/27/93	-.12	-.08	-.07	-.11	-.14	-.11	-.13	-.10	-.10	-.05	-.07	-.12	-.02	-.06	-.04	-.07	-.07	-.07	-.08
1/11/94	-.11	-.08	-.06	-.11	-.14	-.12	-.19	-.13	-.17	-.09	-.12	-.17	-.04	-.09	-.03	-.07	-.05	-.07	-.07
12/5/94	-.10	-.08	-.08	-.11	-.14	-.12	-.18	-.13	-.17	-.09	-.12	-.18	-.04	-.09	-.03	-.08	-.06	-.07	-.08
1/4/96	-.08	-.09	-.04	-.11	-.16	-.14	-.23	-.17	-.21	-.13	-.15	-.23	-.06	-.12	-.04	-.09	-.06	-.09	-.09
5/22/96	NR	NR	NR	-.11	-.14	-.12	-.24	-.16	-.23	-.12	-.19	-.25	-.09	-.15	-.06	-.12	-.10	-.11	-.11
1/29/97	NR	-.05	-.05	-.11	-.16	-.13	-.24	-.17	-.25	-.14	-.20	-.24	-.09	-.14	-.05	-.09	-.08	-.08	-.09
12/11/98	-.07	-.06	-.08	-.11	-.19	-.18	-.27	-.20	-.27	-.16	-.19	-.23	-.08	-.12	-.06	-.11	-.09	-.11	-.12
12/3/99	.08	.04	.05	.12	.18	.14	.26	.18	.29	.16	.24	.28	.12	.16	.06	.12	.09	.11	.11

Resultant vectors based on northing & easting data

1/27/93	.10	.06	.04	.08	.11	.09	.11	.09	.07	.04	.05	.10	.01	.04	.02	.04	.05	.05	.06
1/11/94	.08	.06	.04	.08	.11	.11	.16	.10	.15	.06	.11	.16	.04	.08	.02	.07	.05	.06	.07
12/5/94	.09	.07	.06	.08	.11	.10	.16	.11	.15	.06	.11	.16	.02	.09	.02	.07	.05	.07	.08
1/4/96	.08	.09	.04	.08	.14	.13	.20	.14	.19	.10	.15	.20	.04	.11	.03	.09	.07	.09	.10
5/22/96	NR	NR	NR	.08	.09	.09	.20	.14	.20	.10	.17	.23	.07	.13	.06	.10	.09	.10	.10
1/29/97	NR	.05	.06	.12	.17	.14	.25	.18	.28	.15	.21	.26	.10	.14	.06	.09	.07	.08	.08
12/11/98	.05	.06	.06	.12	.19	.18	.28	.21	.29	.16	.23	.29	.11	.16	.06	.11	.09	.11	.11
12/3/99	.08	.04	.05	.12	.18	.14	.26	.18	.29	.16	.24	.28	.12	.16	.06	.12	.09	.11	.11



Notes: 1) basis of elevation is NAVD 1988 - elevations on this map are 2.8 feet higher than those dated earlier than 1998

2) date of photography for map is 12/97

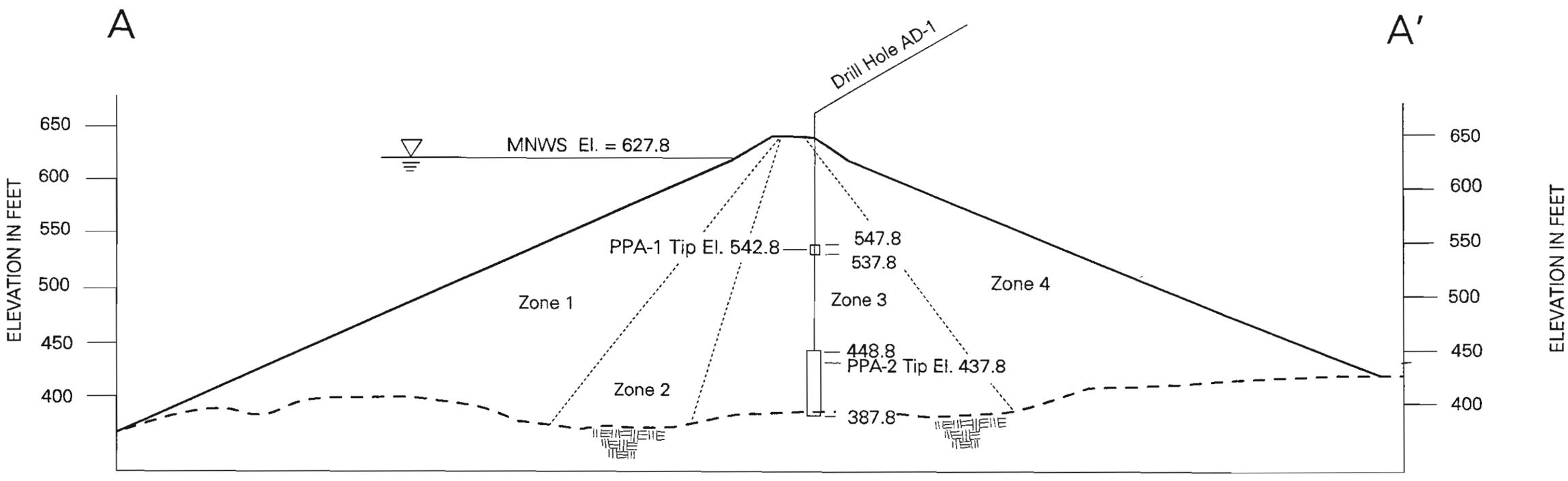
DATE	12/01/98
DESIGN	JLN
DRAWN	JLN
CHECKED	RET

Santa Clara Valley Water District

Topographic Map
Leroy Anderson Dam (No. 72-9)
Surveillance Instrumentation

SCALE 1" = 200'

FIGURE 1



50 0 50 100
Approximate scale in feet

Explanation

Sensing zone = boring with pneumatic piezometer

Note: 1) basis of elevation is NAVD 1988 - elevations on this section are 2.8 feet higher than those dated earlier than 1998

DATE	12/02/98
DESIGN	JLN
DRAWN	JLN
CHECKED	RET

Santa Clara Valley Water District

Cross Section
Leroy Anderson Dam (No. 72-9)
Piezometer Locations

SCALE 1" = 100'

FIGURE 2

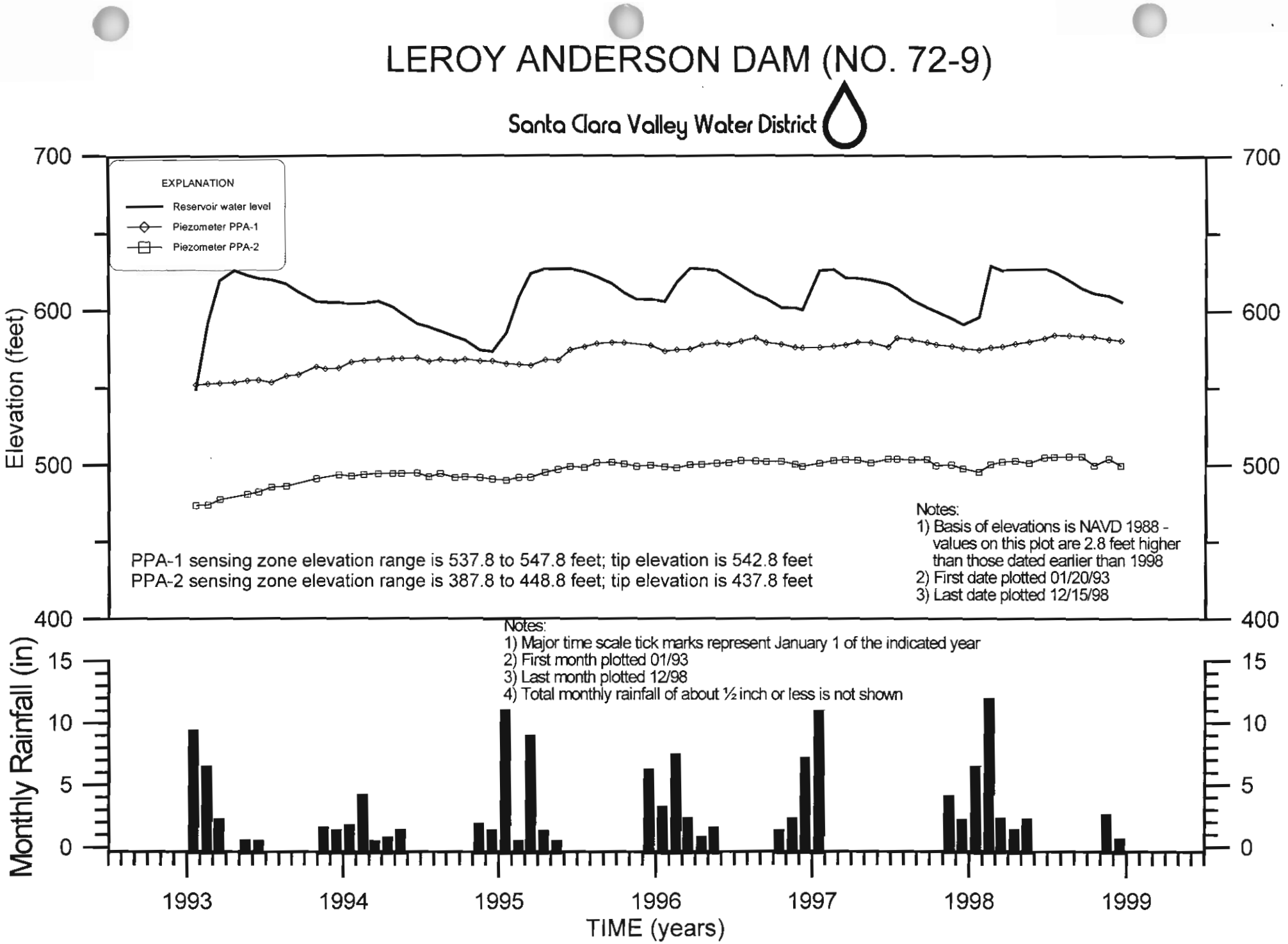


Figure 3. Reservoir Water Level, Piezometric Surfaces, and Monthly Rainfall, January 1993 through December 1998

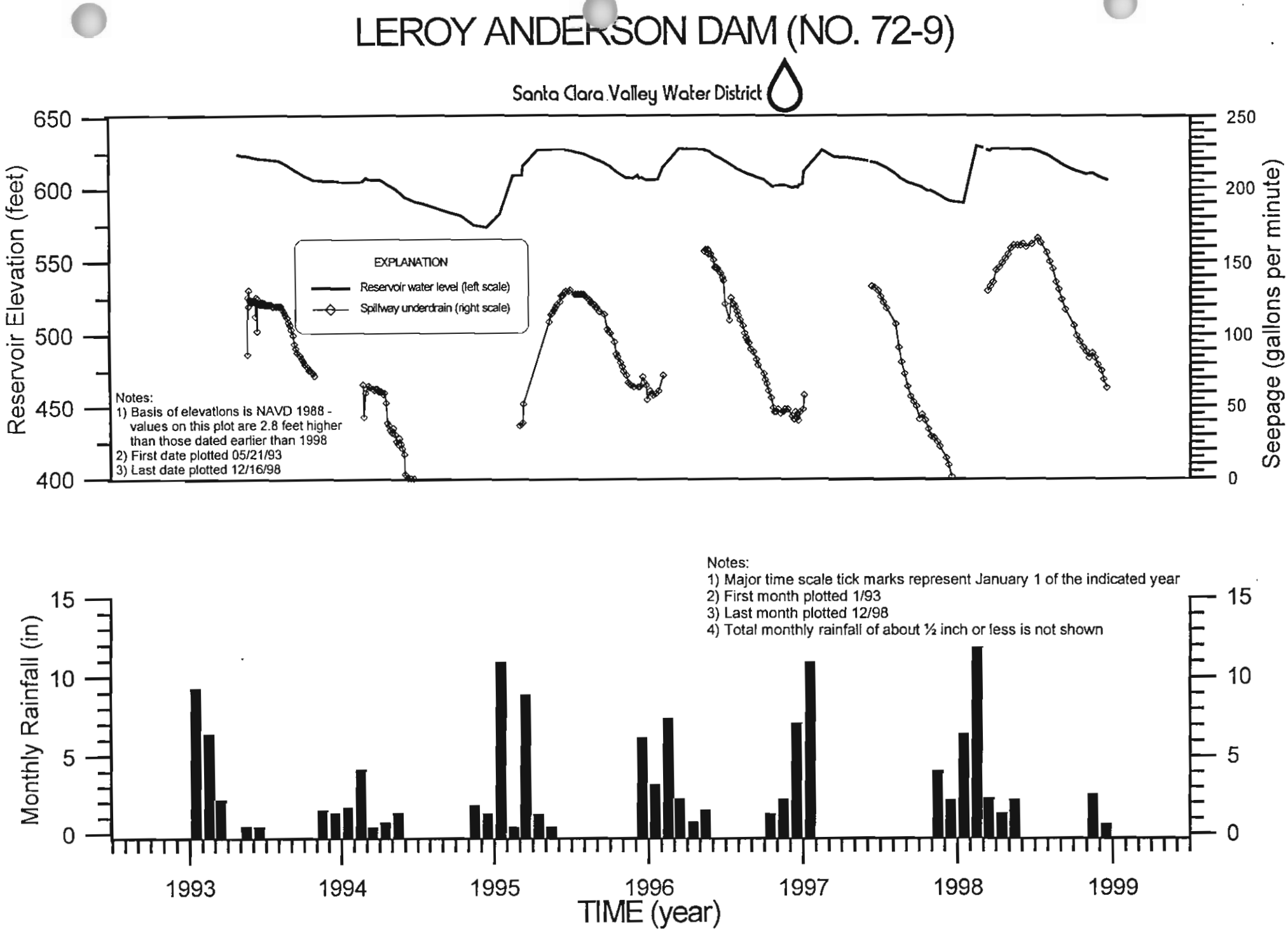


Figure 4. Reservoir Water Level, Spillway Underdrain Flow, and Monthly Rainfall, May 1993 through December 1998

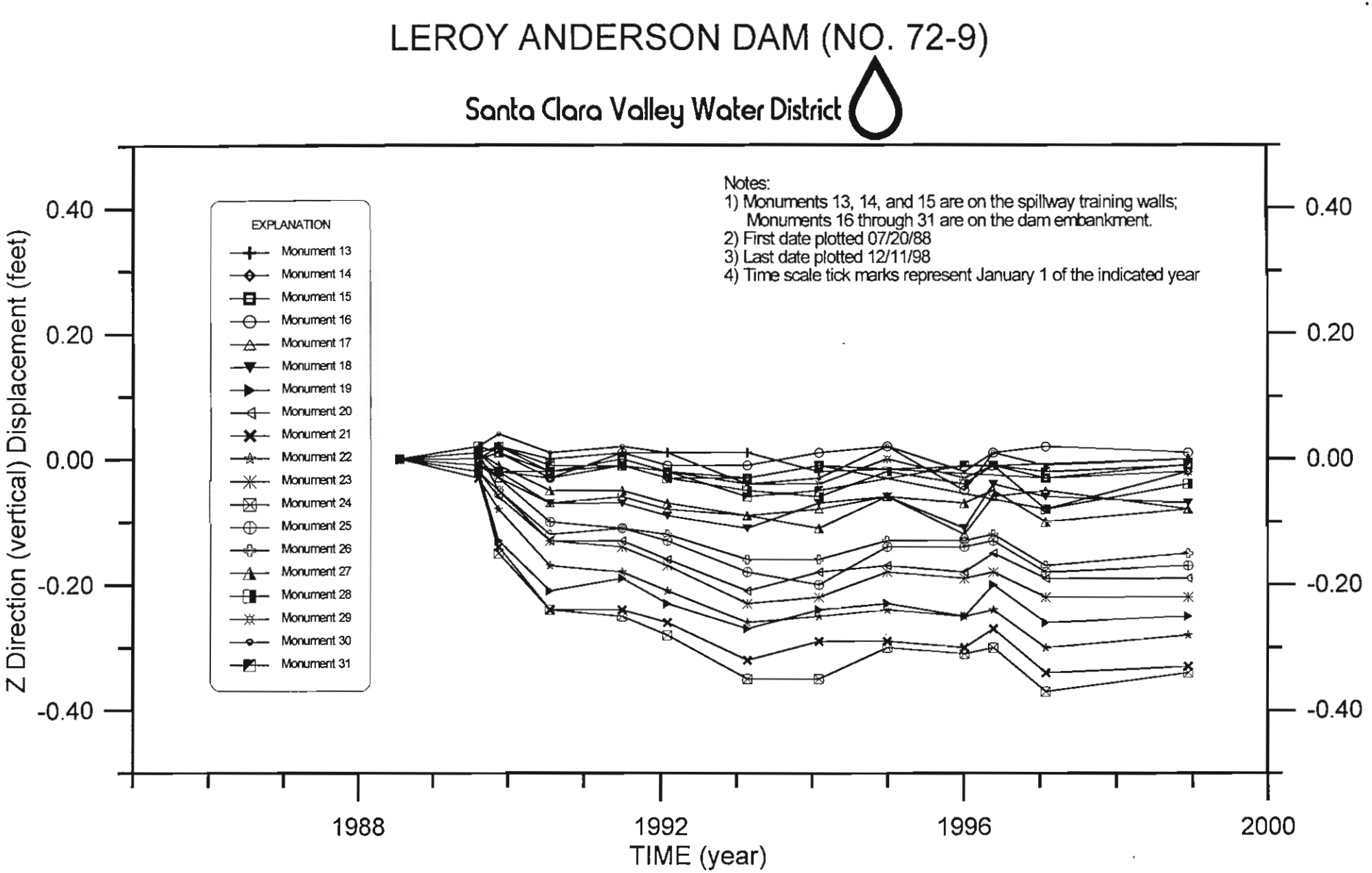


Figure 5. Ten Year Plot of Monument Z Direction (Vertical) Displacement Versus Time, July 1988 through December 1998

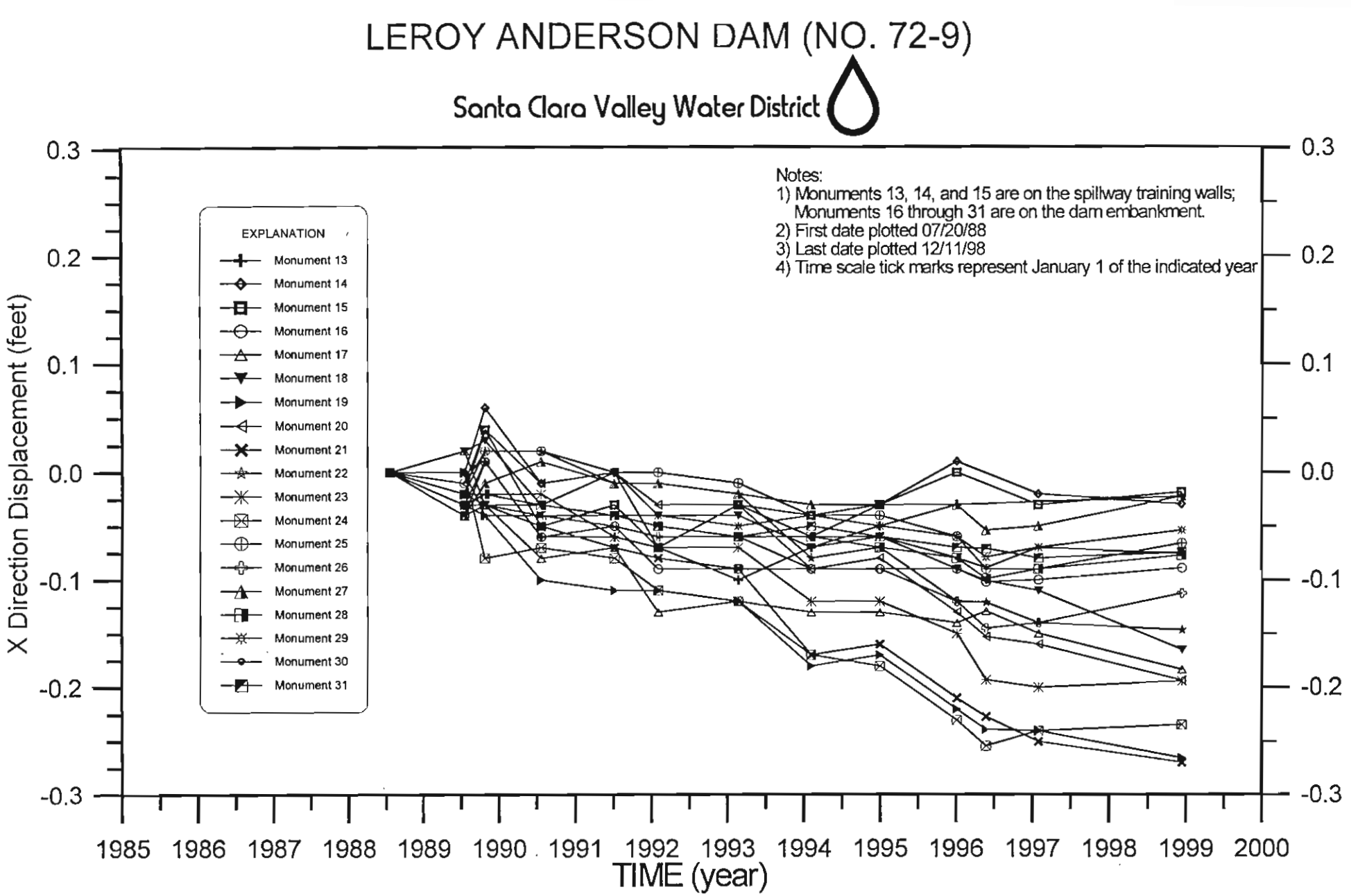


Figure 6. Ten Year Plot of Monument X Direction Displacement Versus Time, July 1988 through December 1998

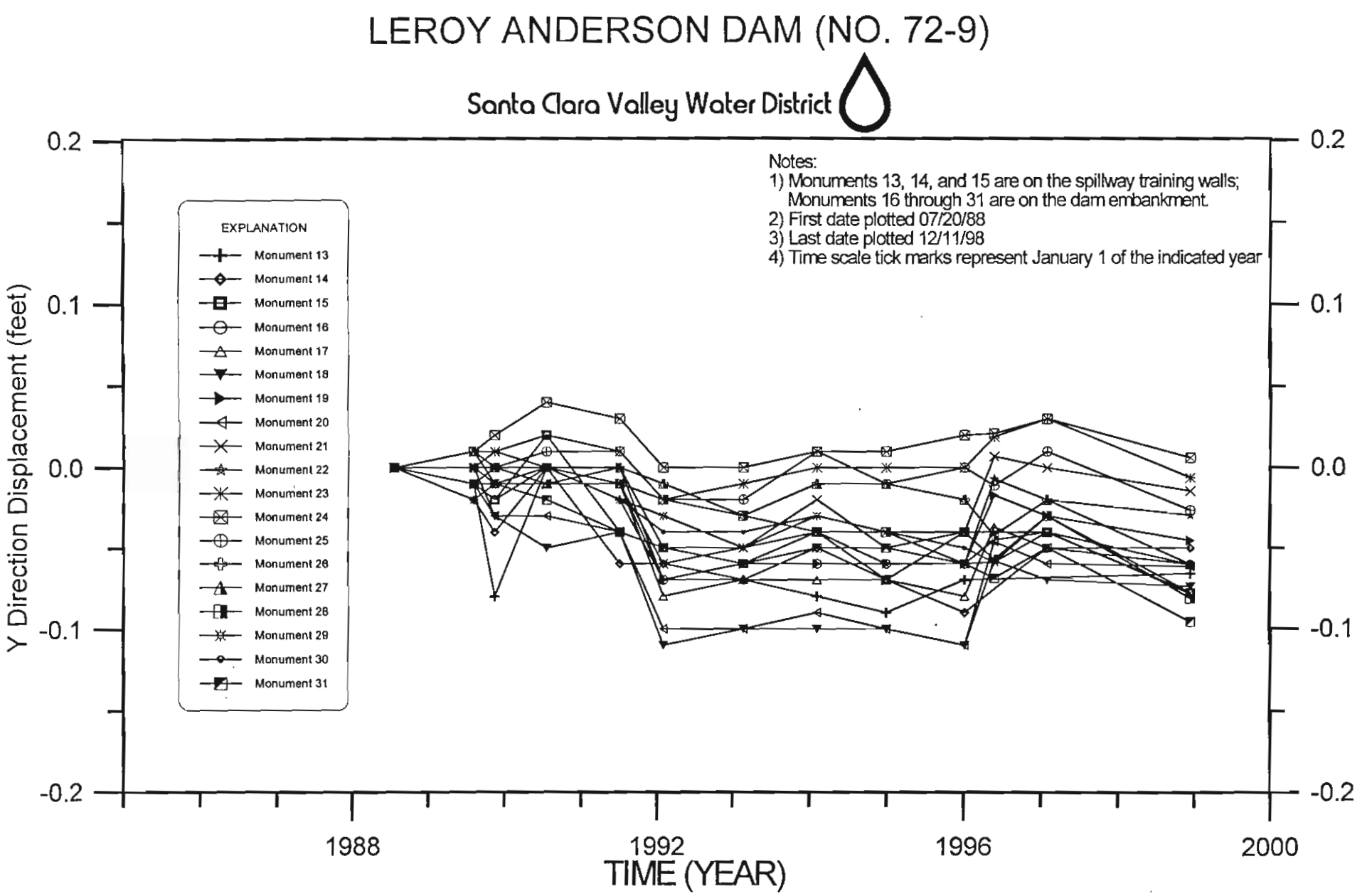
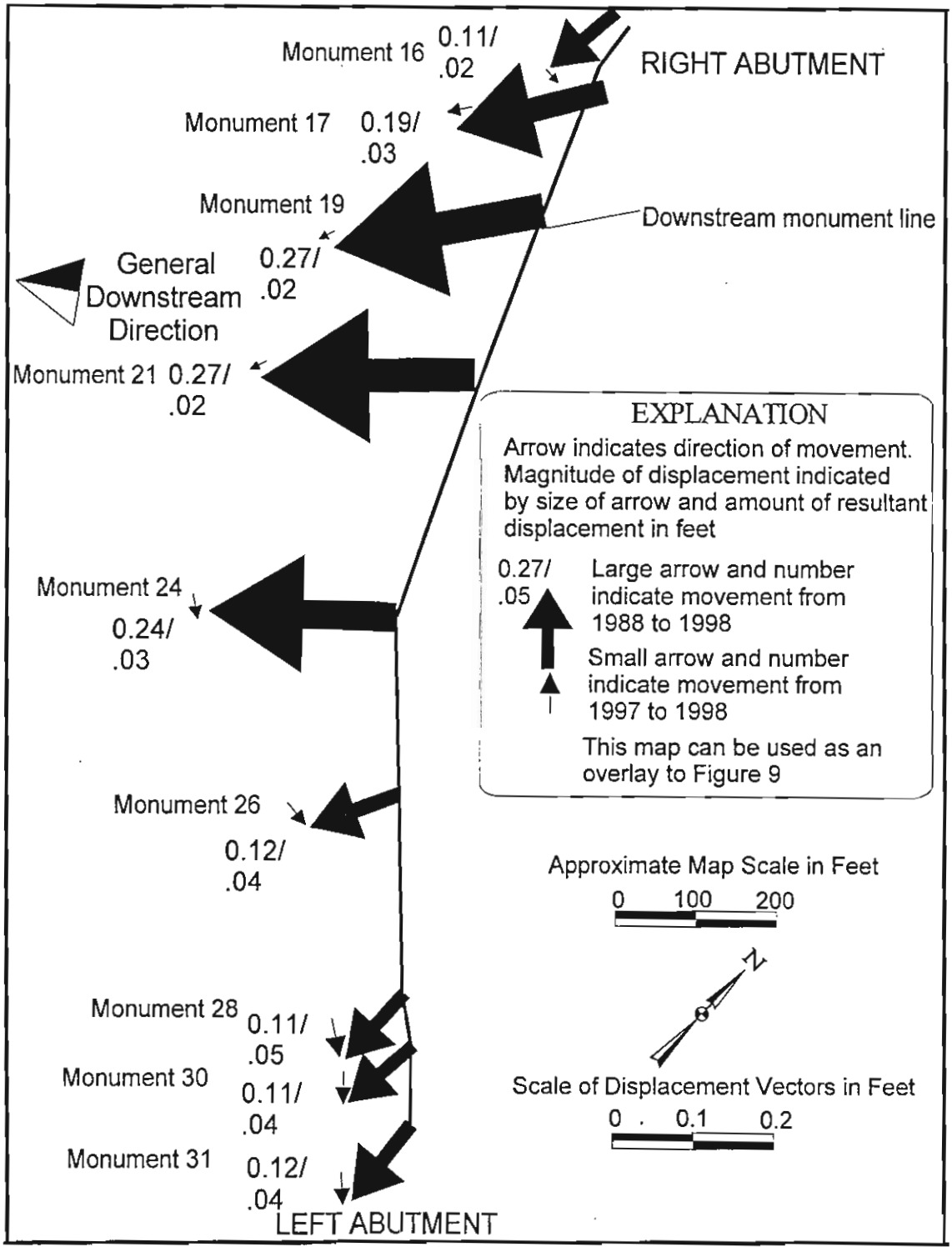


Figure 7. Ten Year Plot of Monument Y Direction Displacement Versus Time, July 1988 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

Santa Clara Valley Water District

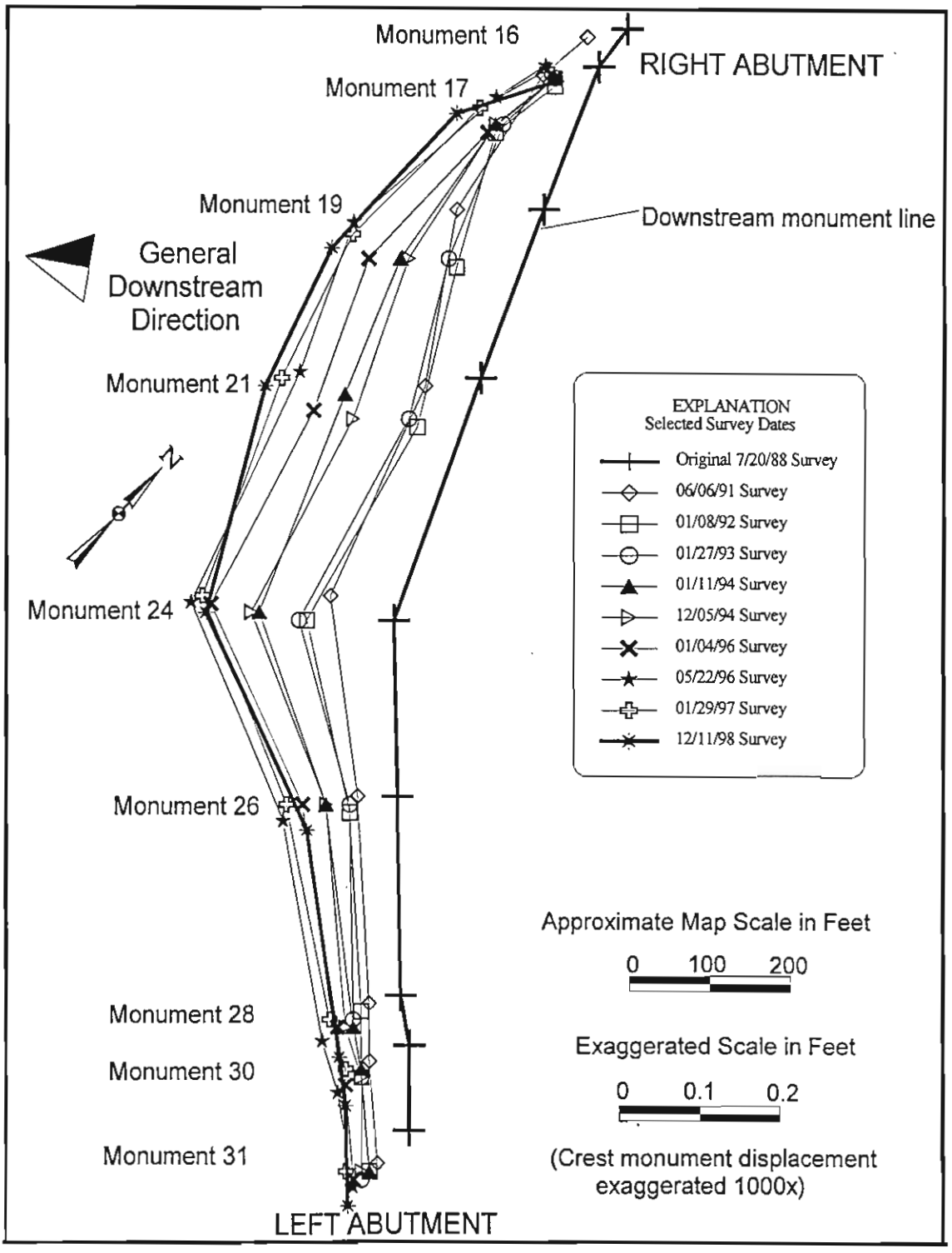


Note: Monuments 16 and 31 are centered on the crest and are included on all plots of downstream and upstream monuments.

Figure 8. Relative Displacement Vectors of Downstream Crest Monument Lateral Location Surveys, July 1988 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

Santa Clara Valley Water District

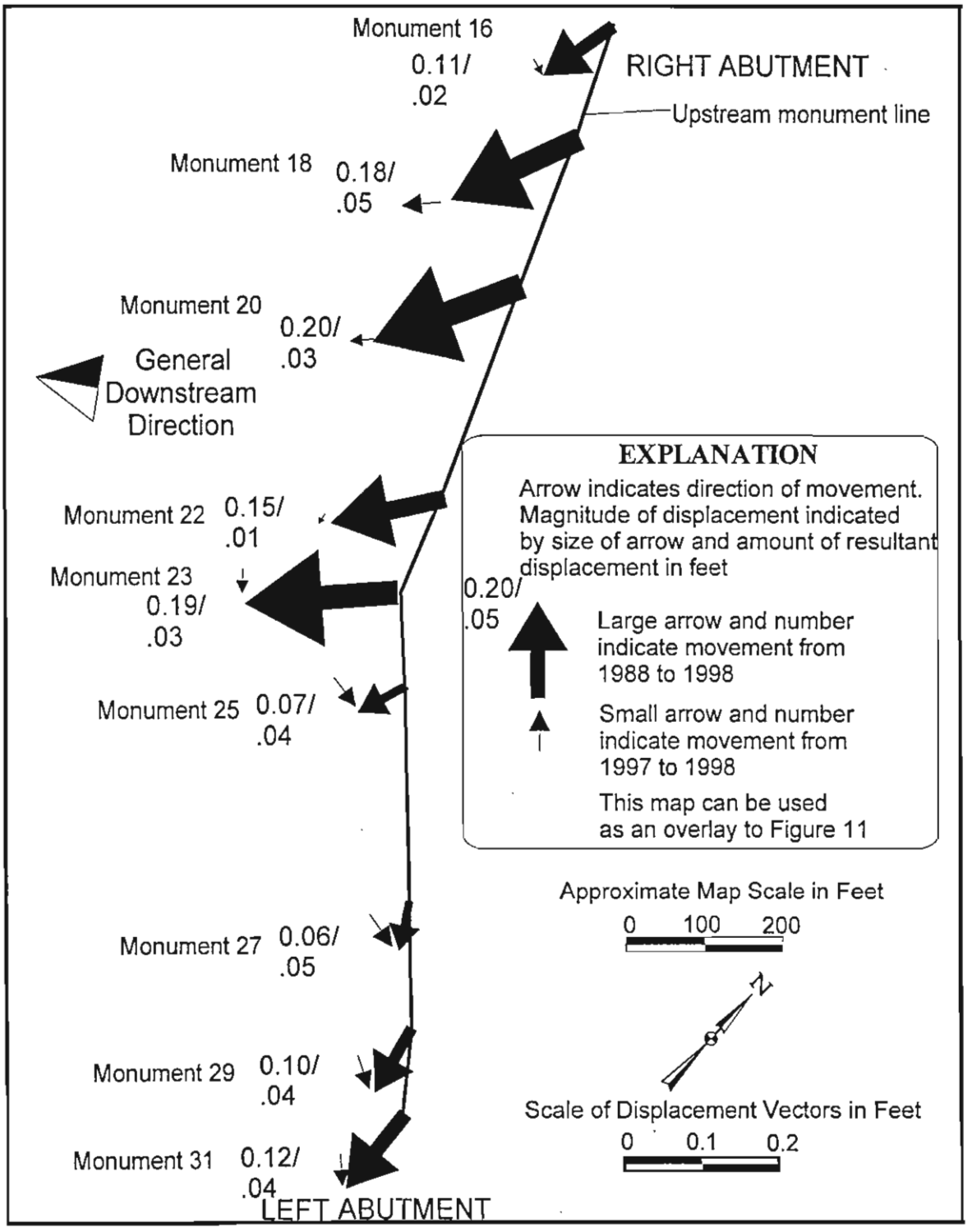


Note: Monuments 16 and 31 are centered on the crest and are included on all plots of downstream and upstream monuments.

Figure 9. Downstream Crest Monument Lateral Location Surveys in Plan View, June 1991 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

Santa Clara Valley Water District

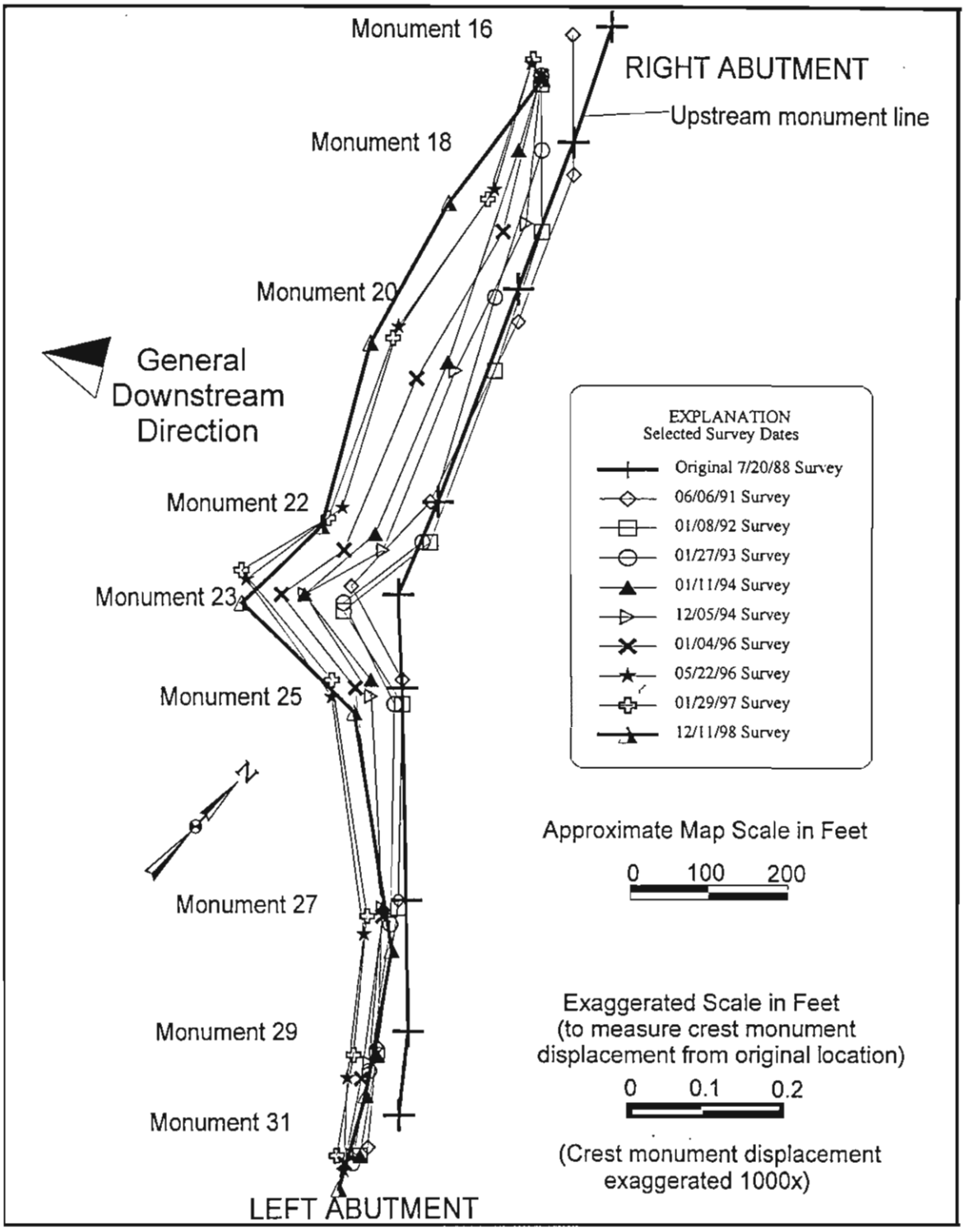


Note: Monuments 16 and 31 are centered on the crest and are included on all plots of downstream and upstream monuments.

Figure 10. Relative Displacement Vectors of Upstream Crest Monument Lateral Location Surveys, July 1988 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

Santa Clara Valley Water District



Note: Monuments 16 and 31 are centered on the crest and are included on all plots of downstream and upstream monuments.

Figure 11. Upstream Crest Monument Lateral Location Surveys in Plan View, June 1991 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

Santa Clara Valley Water District

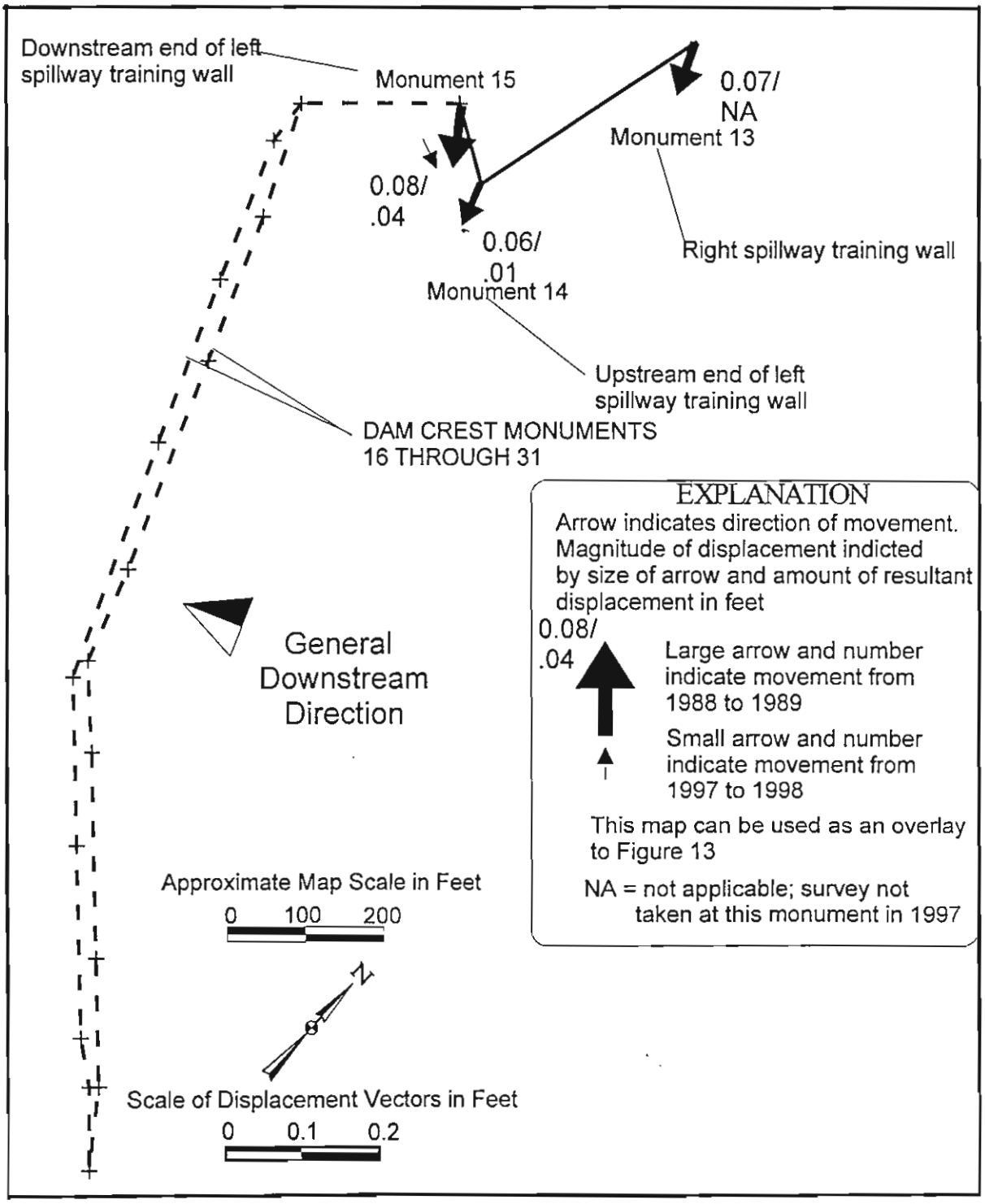


Figure 12. Relative Displacement Vectors of Spillway Training Wall Monument Lateral Location Surveys, July 1988 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

Santa Clara Valley Water District

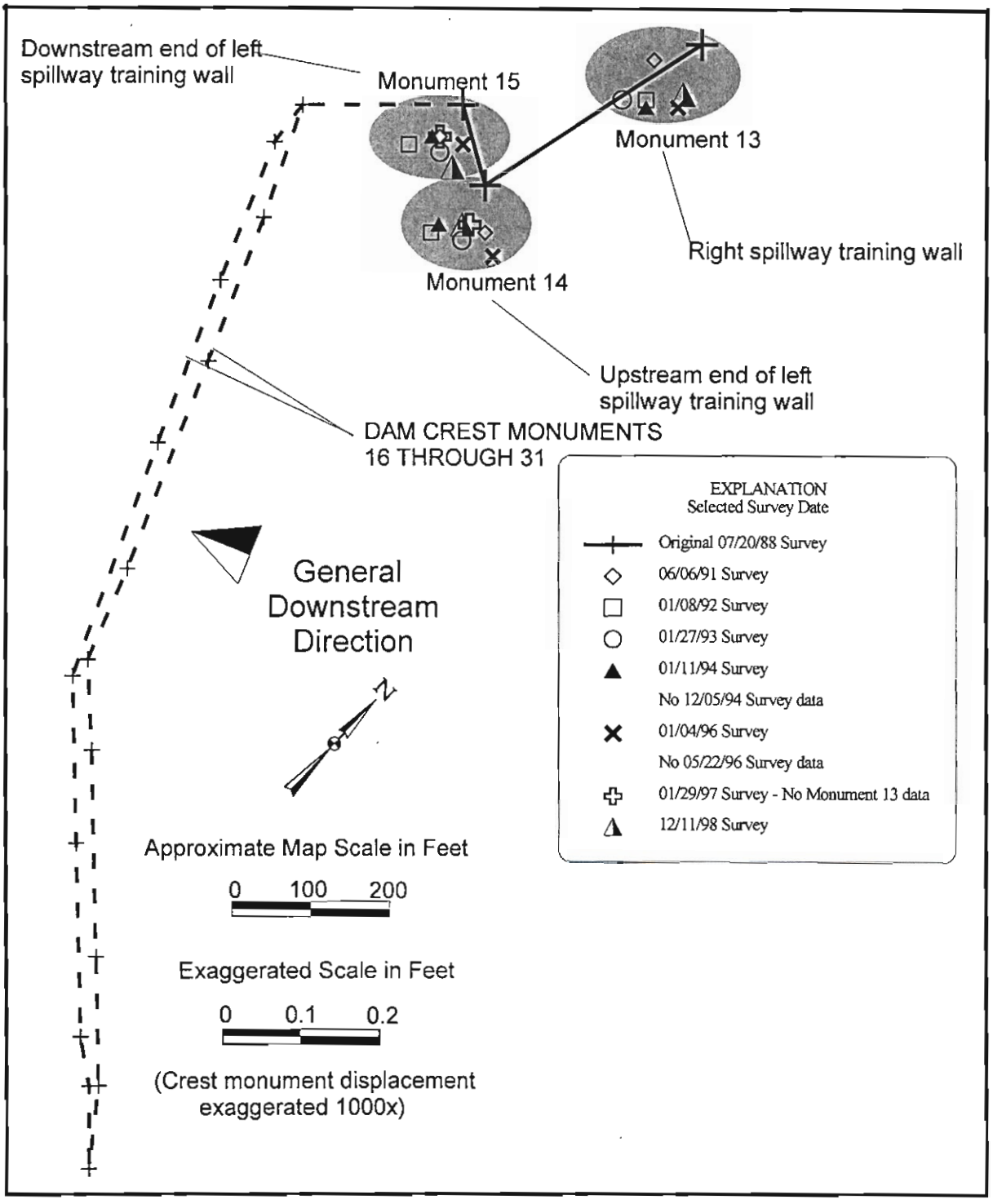


Figure 13. Spillway Training Wall Monument Lateral Location Surveys in Plan View, June 1991 through December 1998

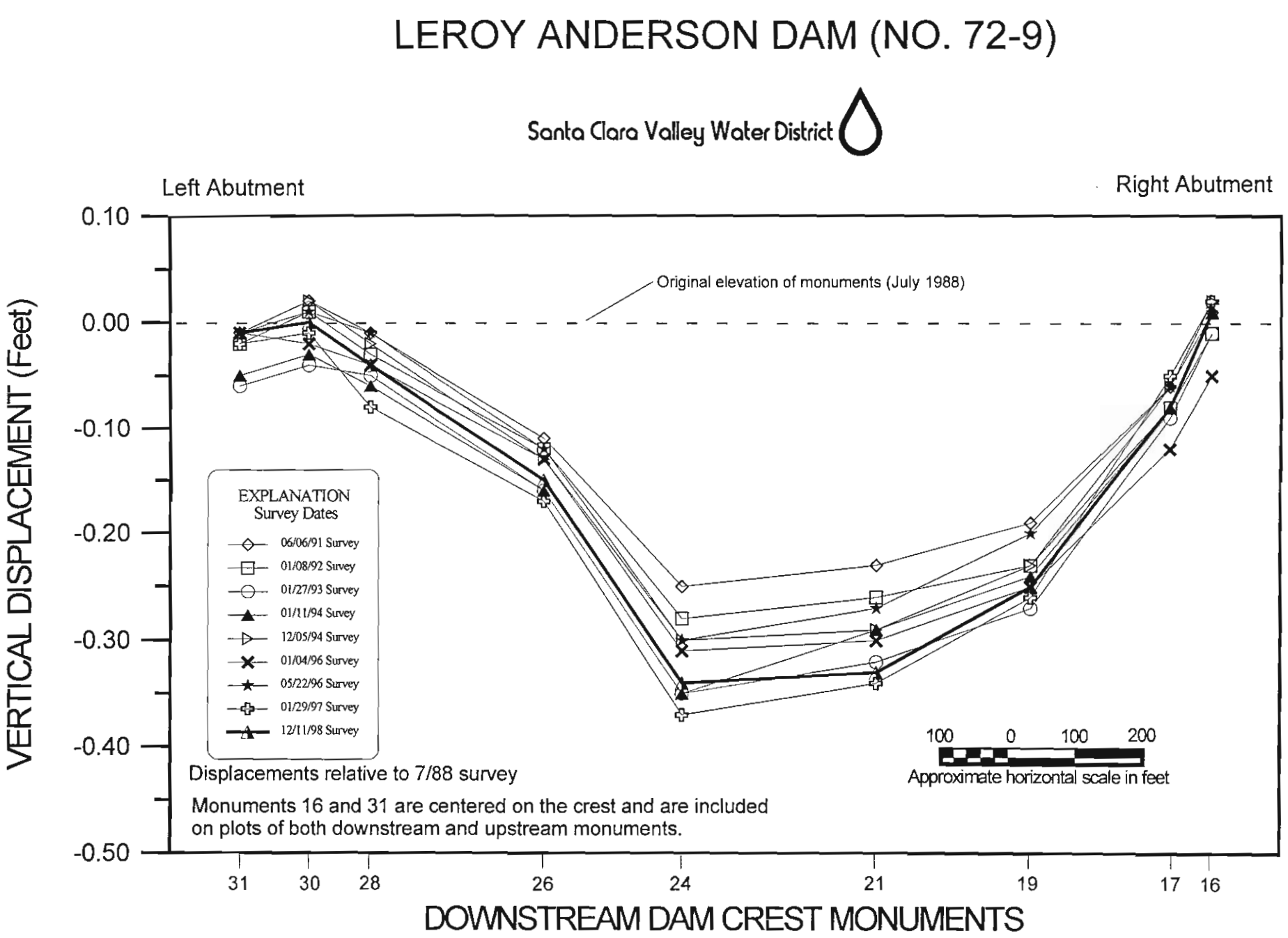


Figure 14. Downstream Crest Monument Vertical Location Surveys in Section View, June 1991 through December 1998

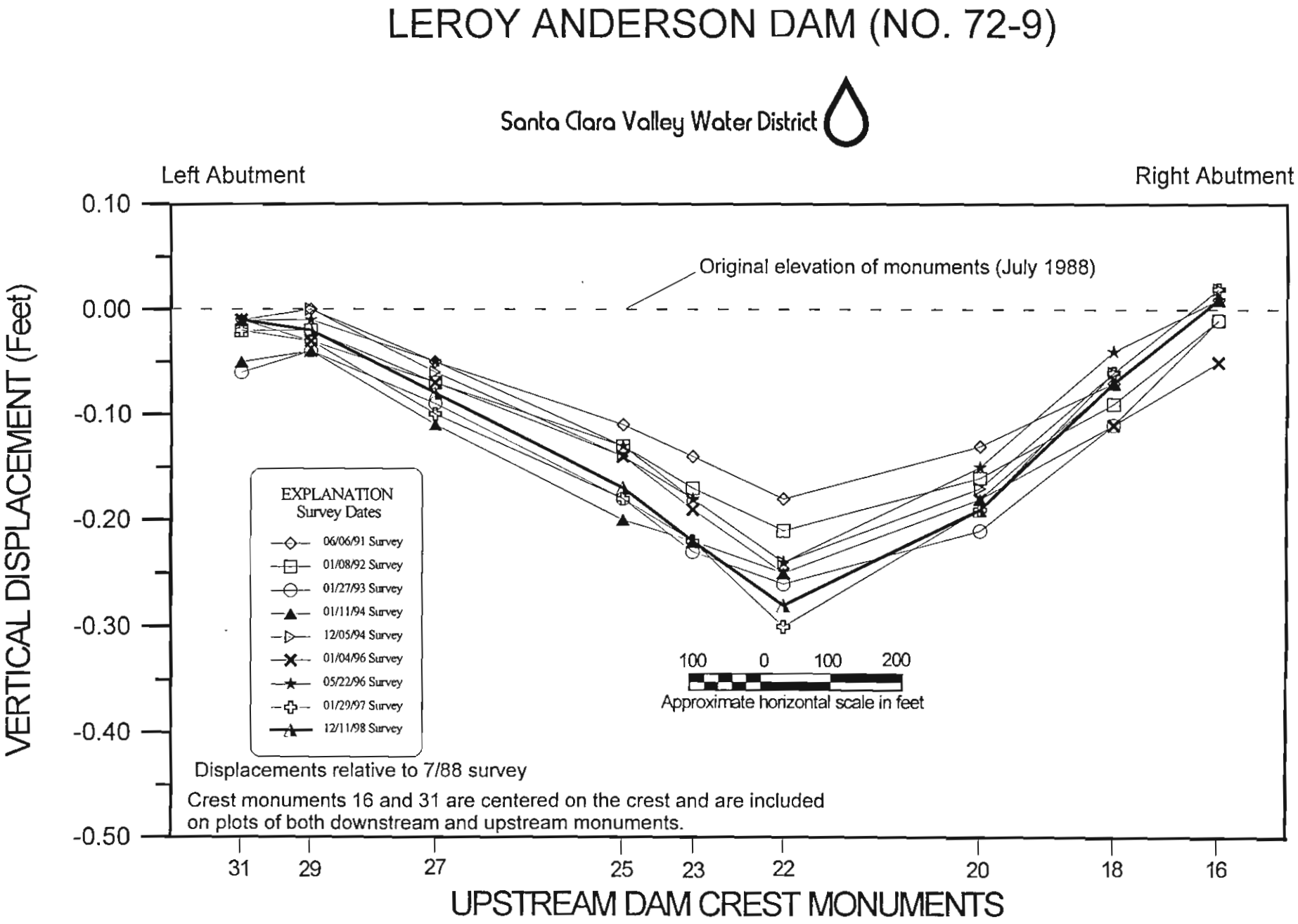


Figure 15. Upstream Crest Monument Vertical Location Surveys in Section View, June 1991 through December 1998

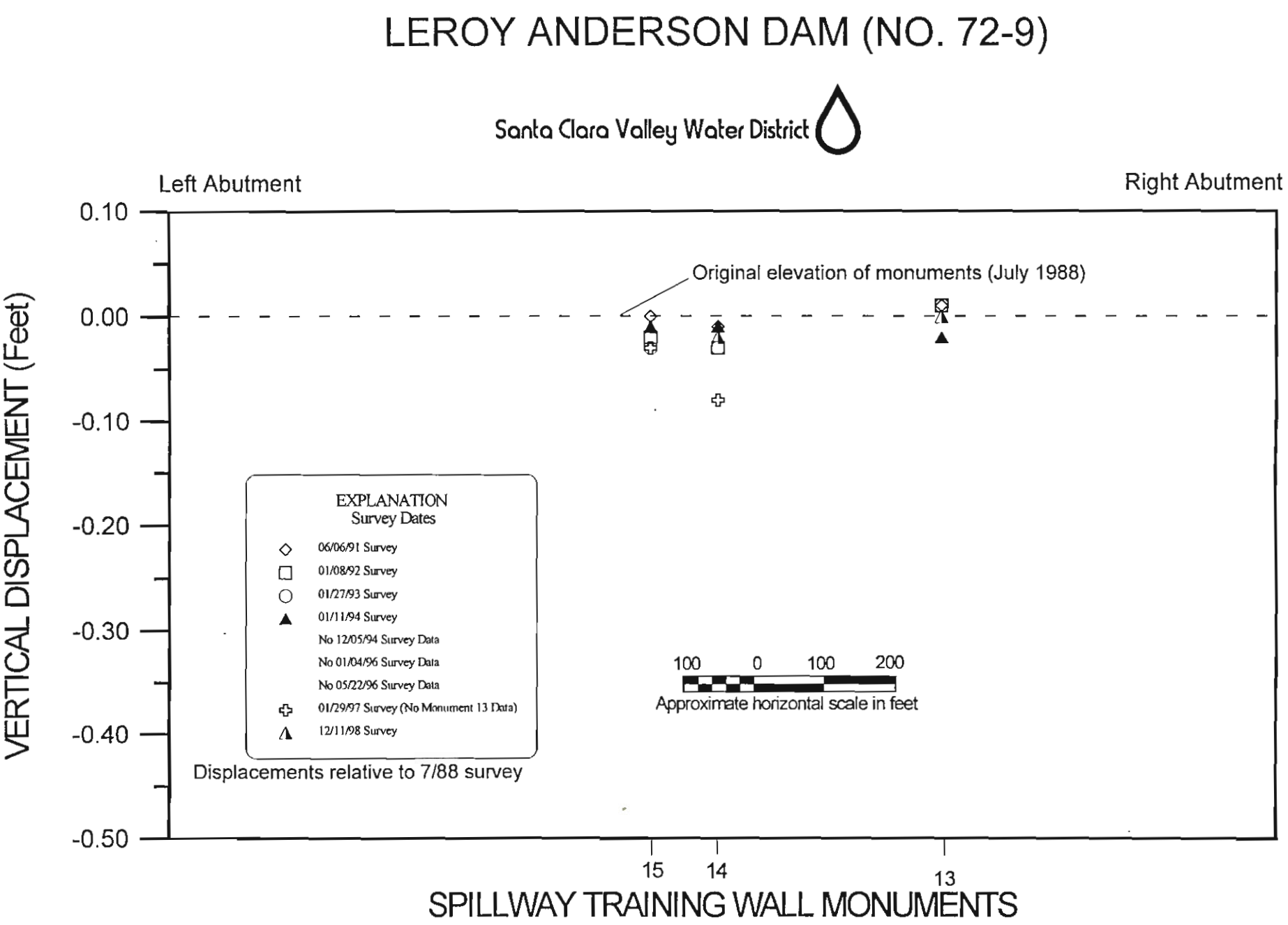


Figure 16. Spillway Training Wall Monument Vertical Location Surveys in Section View, June 1991 through December 1998

LEROY ANDERSON DAM (NO. 72-9)

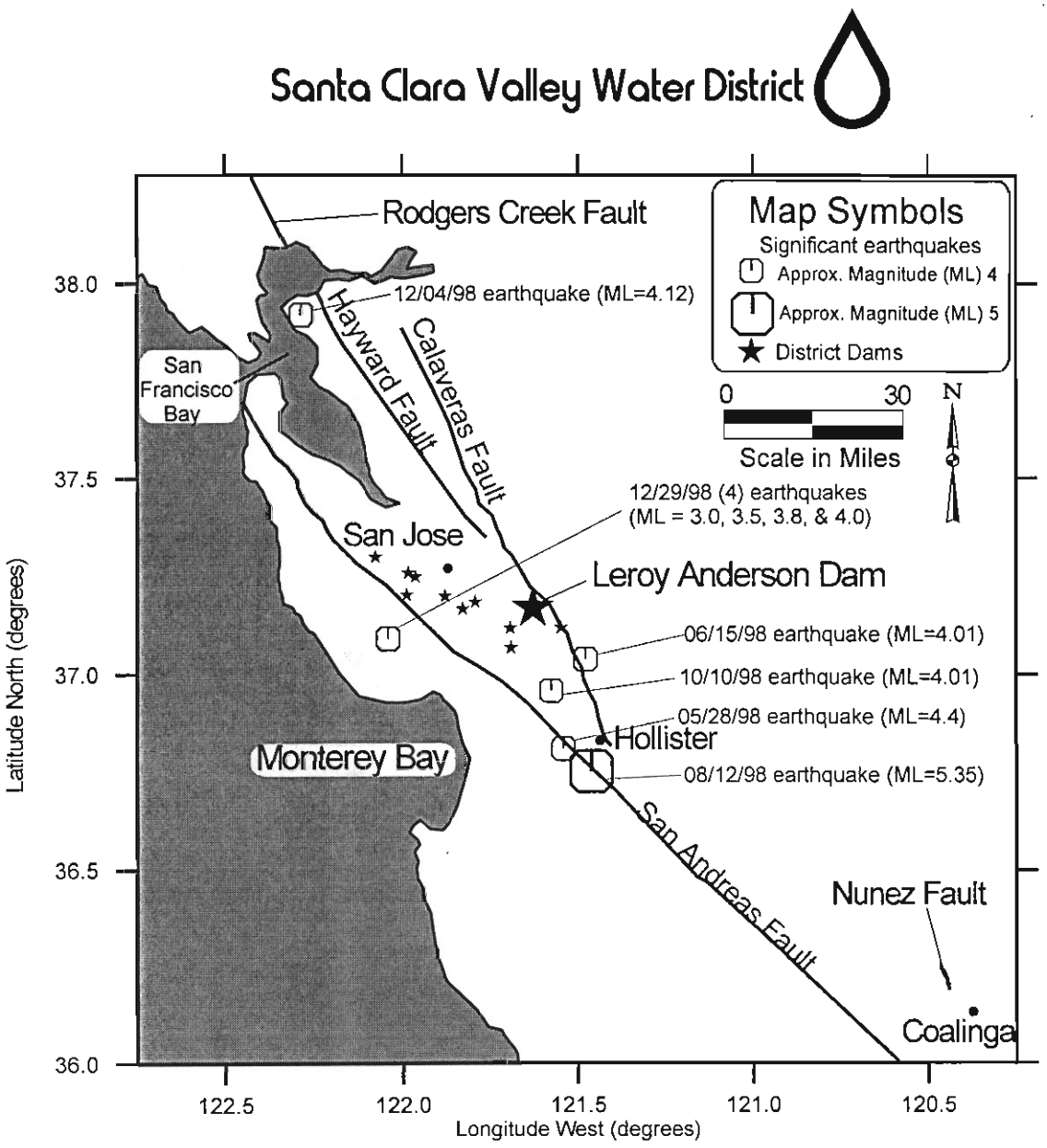


Figure 17. Regional Fault Map, Showing Significant and Noteworthy Earthquakes within 65 Miles of Leroy Anderson Dam, January 1998 through December 1998